Water Quality in the Eastern Iowa Basins

Iowa and Minnesota, 1996–98

U.S. Department of the Interior
U.S. Geological Survey

Circular 1210

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Front cover: Aerial view of the Old Mans Creek basin showing pattern of wooded riparian buffers and cropland typical of the Southern Iowa Drift Plain landform in Iowa. *(Photograph by Doug Schnoebelen, USGS.)*

Back cover: Left, study unit biologist measuring water transparency *(photograph by Stephen Porter, USGS)*; center, study unit staff collecting aquatic organisms from woody debris *(photograph by Stephen Porter);* right, scientists measuring water temperature and dissolved oxygen in Old Mans Creek in preparation for sample collection (*photograph by Debra Sneck-Fahrer, USGS*).

Water Quality in the Eastern Iowa Basins, Iowa and Minnesota, 1996–98

By Stephen J. Kalkhoff, Kimberlee K. Barnes, Kent D. Becher, Mark E. Savoca, Douglas J. Schnoebelen, Eric M. Sadorf, Stephen D. Porter, *and* Daniel J. Sullivan

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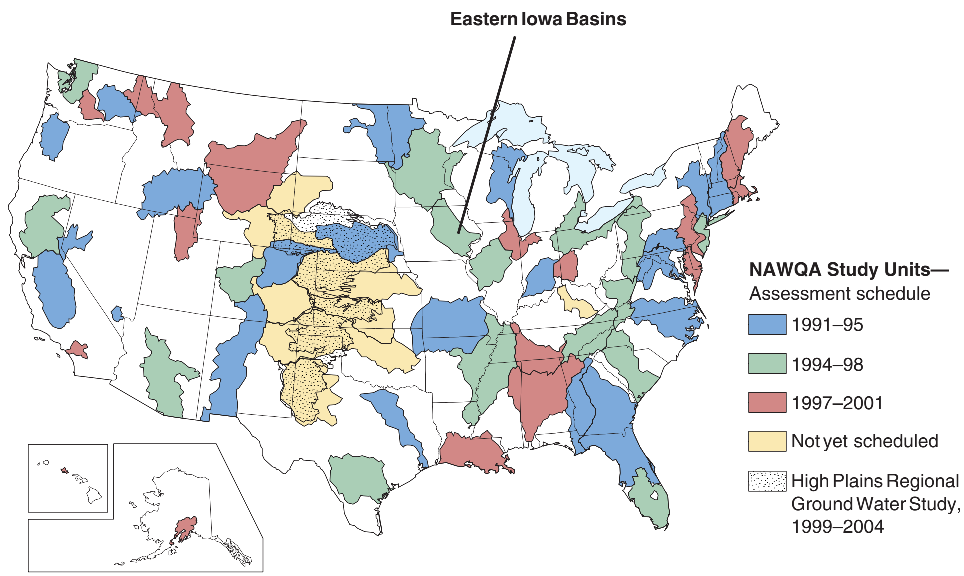
THIS REPORT summarizes major findings about water quality in the Eastern Iowa Basins that emerged from an assessment conducted between 1996 and 1998 by the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program. Water quality is discussed in terms of local and regional issues and compared to conditions found in all 36 NAWQA study areas, called Study Units, assessed to date. Findings also are explained in the context of selected national benchmarks, such as those for drinking-water quality and the protection of aquatic organisms. The NAWQA Program was not intended to assess the quality of the Nation's drinking water, such as by monitoring water from household taps. Rather, the assessments focus on the quality of the resource itself, thereby complementing many ongoing Federal, State, and local drinking-water monitoring programs. The comparisons made in this report to drinking-water standards and guidelines are only in the context of the available untreated resource. Finally, this report includes information about the status of aquatic communities and the condition of in-stream habitats as elements of a complete water-quality assessment.

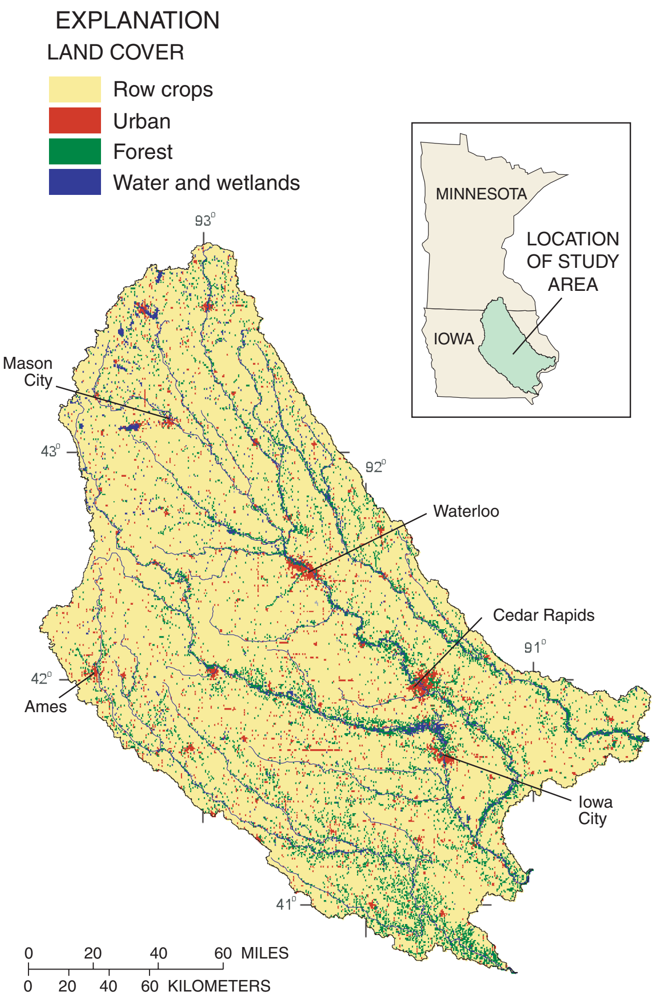
Many topics covered in this report reflect the concerns of officials of State and Federal agencies, water-resource managers, and members of stakeholder groups who provided advice and input during the Eastern Iowa Basins assessment. Basin residents who wish to know more about water quality in the areas where they live will find this report informative as well.



THE NAWQA PROGRAM seeks to improve scientific and public understanding of water quality in the Nation's major river basins and ground-water systems. Better understanding facilitates effective resource management, accurate identification of water-quality priorities, and successful development of strategies that protect and restore water quality. Guided by a nationally consistent study design and shaped by ongoing communication with local, State, and Federal agencies, NAWQA assessments support the investigation of local issues and trends while providing a firm foundation for understanding water quality at regional and national scales. The ability to integrate local and national scales of data collection and analysis is a unique feature of the USGS NAWQA Program.

The Eastern Iowa Basins is one of 51 water-quality assessments initiated since 1991, when the U.S. Congress appropriated funds for the USGS to begin the NAWQA Program. As indicated on the map, 36 assessments have been completed, and 15 more assessments will conclude in 2001. Collectively, these assessments cover about one-half of the land area of the United States and include water resources that are available to more than 60 percent of the U.S. population.

SUMMARY OF MAJOR FINDINGS

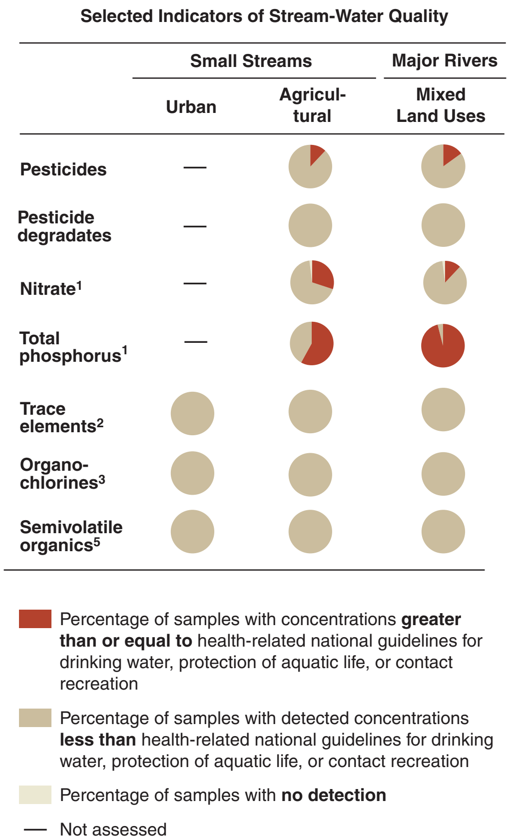


The Eastern Iowa Basins Study Unit encompasses the Wapsipinicon, the Cedar, the Iowa, and the Skunk River Basins and covers about 19,500 mi^2 in eastern Iowa and southern Minnesota. In 1990, about 40 percent of the more than 1 million people in the Study Unit were concentrated in cities with populations of greater than 20,000 people. Cedar Rapids is the only city with a population greater than 100,000. Ground water is the major source for municipal, industrial, and domestic supplies. During the study, Iowa City was the largest municipal user of surface water. Over 90 percent of the land in the Study Unit is used for agricultural purposes. Forested areas account for only 4 percent of the land. Data from Eros Data Center, 1994.

Stream And River Highlights

Nitrogen and phosphorus concentrations in streams in the Eastern Iowa Basins Study Unit rank as some of the highest in the Corn Belt (see map, p. 8) as well as the Nation and were higher than the drinking-water standard in many samples. These conditions reflect intensive use of the land for growing crops and dense populations of livestock in some basins.

- Nitrate concentrations in 22 percent of the stream samples exceeded the U.S. Environmental Protection Agency (USEPA) drinking-water standard of 10 mg/L (milligrams per liter). The standard was most frequently exceeded during June, soon after spring fertilizer application. Although many of the streams sampled are not currently used for drinking-water supplies, the Cedar and Iowa Rivers are the direct or indirect source for Cedar Rapids and Iowa City—two of the largest cities in the study area.
- The highest nitrate concentrations occurred in medium-sized streams draining basins with the most intensive row-crop agriculture and in a stream draining a basin with both intensive row-crop agriculture and dense concentrations of large-scale animal feeding operations. Nitrate concentrations in these streams exceeded 10 mg/L in almost 50 percent of the samples. Conversely, nitrate concentrations were lowest in basins that had greater percentages of pasture, grassland, and forest.
- Total phosphorus concentrations frequently (75 percent of the samples) exceeded the 0.1-mg/L USEPA-recommended goal to minimize algal growth in rivers. Total phosphorus concentrations were greatest in streams and rivers that drain basins with more highly erodible soils and in large river basins that contain the largest cities and towns in the Study Unit.
- The large amounts of nitrogen and phosphorus that are transported to the Mississippi River from the Study Unit represent an economic loss to farmers and a potential environmental threat to downstream waters. The estimated annual loss of 17 to 41 lb/acre (pounds per acre) of nitrogen and 1.2 to 1.5 lb/acre of phosphorus represents a potential loss in crop yield or the cost of additional fertilizer needed to compensate for that flushed from the fields. Nutrients transported to the Mississippi River likely reach the Gulf of Mexico where they contribute to eutrophication and hypoxia.
- Although the use of herbicides and insecticides in the Study Unit is among the most intense nationwide, herbicide concentrations in streams were not among the highest 25 percent nationally, and insecticide concentrations were in the lowest 25 percent nationally. Breakdown compounds (degradates), whose widespread occurrence has only recently been discovered and about which little is known of the human and environmental effects, generally accounted for the majority of the pesticide compounds present in rivers and streams.
- The most commonly used herbicides were the most frequently detected and were generally present in the greatest concentrations. Atrazine and metolachlor were detected in all stream samples. Concentrations generally ranged from 0.1 to 1.0 µg/L (microgram per liter). Atrazine concentrations exceeded the USEPA 3.0-µg/L drinking-water standard in about 10 percent of the samples; exceedances occurred mainly during late-spring runoff.
- Acetochlor, a conditionally registered herbicide that is intended to replace several other commonly used herbicides, was frequently detected, but concentrations were less than 0.1 µg/L in 75 percent of the samples. Mean annual acetochlor concentrations did not exceed the 2.0-µg/L USEPA registration requirement at any site, but concentrations did exceed that level in about 3 percent of the individual samples. The maximum concentration measured during the study (10.6 µg/L) exceeded the level that would require biweekly sampling by water-supply systems.
- Alachlor, metolachlor, and acetochlor degradates are present in relatively high concentrations throughout the year, indicating that they are more persistent than their parent compounds.
- Carbofuran and chlorpyrifos, insecticides that have been identified as posing a high risk to aquatic insects and mussels, were present in as much as 60 percent of the monthly samples during the summer when these insecticides are normally applied.
- Riparian buffer zones influence the quality of water in streams and rivers. Biological communities respond to tree density in riparian buffer zones. Invertebrate taxa indicative of good stream quality increased with increased numbers of trees. In contrast, streams that were not shaded by trees contained large algal growths considered indicative of eutrophication.



Major influences on streams and rivers

- Agricultural storm runoff
- Animal feeding operations
- Tile-line drainage
- Urban areas

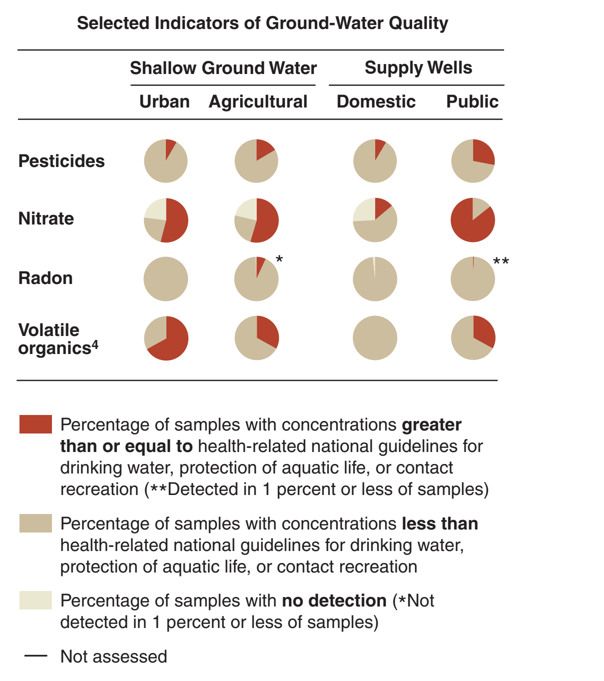
Ground-Water Highlights

Compared to surface water, ground water in the Eastern Iowa Basins had substantially lower nutrient concentrations and less frequent detections. Land use, however, had a substantial effect on the quality of water in alluvial aquifers. Pesticide degradates were some of the most commonly detected constituents in these aquifers. Nitrate and methyl *tert*-butyl ether (MTBE) exceeded the USEPA standard or advisory in some of the samples. In contrast, bedrock aquifers, which are generally protected by clay and shale layers, typically had low nitrate concentrations and low frequency of pesticide detections.

- Nitrate concentrations generally decreased with depth in the alluvial aquifers. Biological denitrification may result in decreased nitrate concentration with depth, but it is also possible that the deeper water infiltrated during past years when less fertilizer was used for crops.
- Nutrients move from ground water to streams by natural drainage and tile lines. Nitrate concentrations in 24 of 25 medium-sized streams exceeded 10 mg/L during the sampling period in May 1998 when streamflow originated primarily from ground-water discharge. Nitrate concentrations consistently exceeded 10 mg/L in water from a selected tile line draining to the Iowa River.
- Pesticides were detected in alluvial aquifers underlying both agricultural and urban areas, but shallow ground water in agricultural areas contained greater concentrations than urban areas. A greater variety of pesticide compounds was detected in urban areas than agricultural areas, reflecting a more diverse usage.
- Pesticides most commonly detected in the alluvial aquifers underlying urban areas were atrazine, prometon, and metolachlor. Pesticide concentrations did not exceed established drinking-water standards.
- With the exception of atrazine and metolachlor and prometon in urban areas, pesticides were infrequently detected in alluvial aquifers. Pesticide degradates generally were more commonly detected in the alluvial aquifers than their parent compounds. The greater presence of degradates indicates that many pesticides break down in the soil and that the resulting pesticide degradates are transported to the shallow aquifers.
- MTBE, a common gasoline additive used to increase the octane content or ensure cleaner burning, was detected in 23 percent of samples from alluvial aquifers in urban areas. Concentrations exceeded the USEPA drinking-water advisory in samples from 6 percent of the wells.

Major influences on ground water

- Lawn, garden, and agricultural fertilizers
- Agricultural and urban pesticides
- Leaking underground fuel-storage tanks



[1] Phosphorus and nitrogen, sampled in water.
[2] Arsenic, mercury, and metals, sampled in sediment, fish tissue, and water.
[3] DDT and PCBs, sampled in sediment and fish tissue.
[4] Solvents, refrigerants, fumigants, and gasoline compounds, sampled in water.
[5] By-products of fossil-fuel combustion; components of coal and crude oil, sampled in sediment and fish tissue.

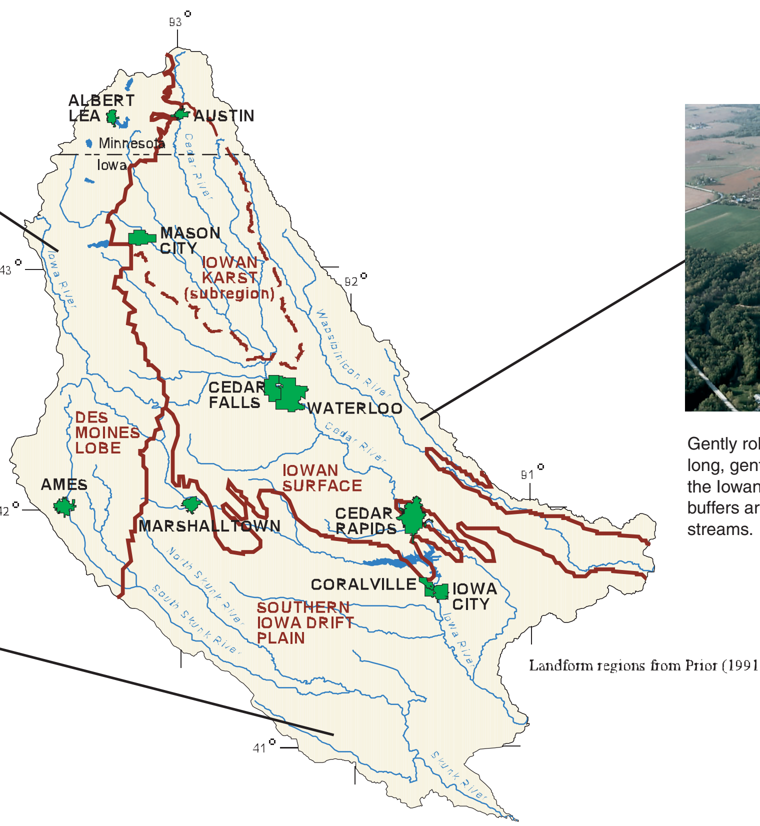
The Eastern Iowa Basins Study Unit encompasses the Wapsipinicon, the Cedar, the Iowa, and the Skunk River Basins and encompasses about 19,500 mi^2 (square miles) in eastern Iowa and southern Minnesota (fig. 1). The four major rivers in the Study Unit generally flow in a southeasterly direction and empty into the Mississippi River. The basins of these four major rivers are relatively long and narrow. The Wapsipinicon River originates in southeastern Minnesota and extends about 225 mi (miles) to its confluence with the Mississippi River. The Wapsipinicon River Basin has a drainage area of 2,540 mi^2. The Cedar River originates in southern Minnesota and joins the Iowa River about 30 mi upstream from the mouth of the Iowa River. The Iowa River originates in north-central Iowa. The Iowa and the Cedar River Basins cover 12,640 mi^2, more than 90 percent of which is in Iowa. The Skunk River originates in central Iowa and drains about 4,350 mi^2.

Geology

Glaciers created a land surface with three distinct regions in the Eastern Iowa Basins Study Unit: the Des Moines Lobe, the Iowan Surface, and the Southern Iowa Drift Plain (fig. 1). The Des Moines Lobe is characterized by low relief with some distinct ridges near the eastern boundary and occasional depressions that form lakes, ponds, and swamps. Glacial till is the dominant surficial material, and alluvium is present along the streams. Poorly drained soils have developed on the tills. The Iowan Surface has gently rolling topography with long slopes, low relief, and a mature drainage pattern. The surficial material is primarily glacial drift with thin layers of windblown loess on the ridges and alluvium near the streams. A subregion of the Iowan Surface (Iowan Karst) was defined for this study in an area where bedrock is close to the land surface. In the Southern Iowa Drift Plain, streams have eroded deeply into the glacial drift and loess mantle to produce a steeply rolling terrain with broad, flat drainage divides. Moderately well-drained soils have developed on the loess.

The Des Moines Lobe is characterized by flat topography and fertile soils; conditions ideal for growing corn and soybeans.

The more steeply rolling terrain of the Southern Iowa Drift Plain is extensively farmed but has relatively more forests, pastures, and grassland than the other landform regions.



Gently rolling topography with long, gentle slopes characterize the Iowan Surface. Wooded buffers are present along many streams.

Figure 1. Glacial deposits formed three major landforms with characteristic soils and topography in the Eastern Iowa Basins.

Climate

Water originates as rainfall in late spring through late fall and as snow during winter and early spring. Average annual precipitation in the basins ranges from about 30 inches in the northwestern part of the Study Unit to about 36 inches in the southeast. The greatest rainfall typically occurs during the growing season in spring and summer. The mean April-to-October precipitation is about 25 inches. The most intense 24-hour rainfall (5-year recurrence interval) can be more than 4 inches. Snowfall has been recorded from September to May. The greatest 24-hour snowfall seldom (less than 25 percent of the years) exceeds 10 inches. Yearly rainfall during the study period ranged from below average in 1996 to about average in 1997 and above average in 1998.

Land Use

Because water flows over the land surface or infiltrates the soil, human activities may have a substantial effect on the quality of ground and surface water. The production of row crops, such as corn, and cover crops, such as alfalfa and small grains, constitutes the major land use in the Study Unit. Land near the streams and rivers has a combination of crops and forests. About 40 percent of the more than 1 million people in the Study Unit are concentrated in cities with populations greater than 20,000.

Water Use

Water used for household, municipal, commercial, industrial, and agriculture purposes originates primarily from ground water. Surface water, although an important supply for several larger cities including Cedar Rapids and Iowa City, is used primarily for cooling water in the generation of electric power.

Water that infiltrates through the soil into underlying sand and gravel deposits and ultimately into the underlying bedrock formations is used as a water supply for about 94 percent of the population in the Eastern Iowa Basins Study Unit. Rivers and streams are the source of public-water supplies for about 6 percent of the population (fig. 2).

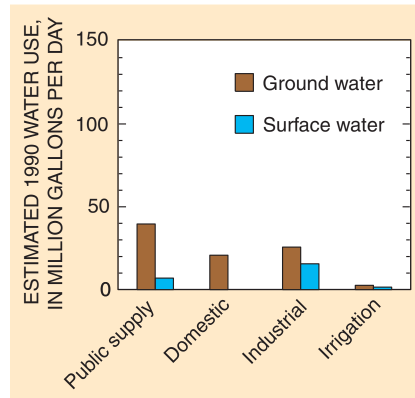


Figure 2. An abundant ground-water resource provides water to municipalities, homes, and industry. Ground water is used by more than 90 percent of the population in the Study Unit.

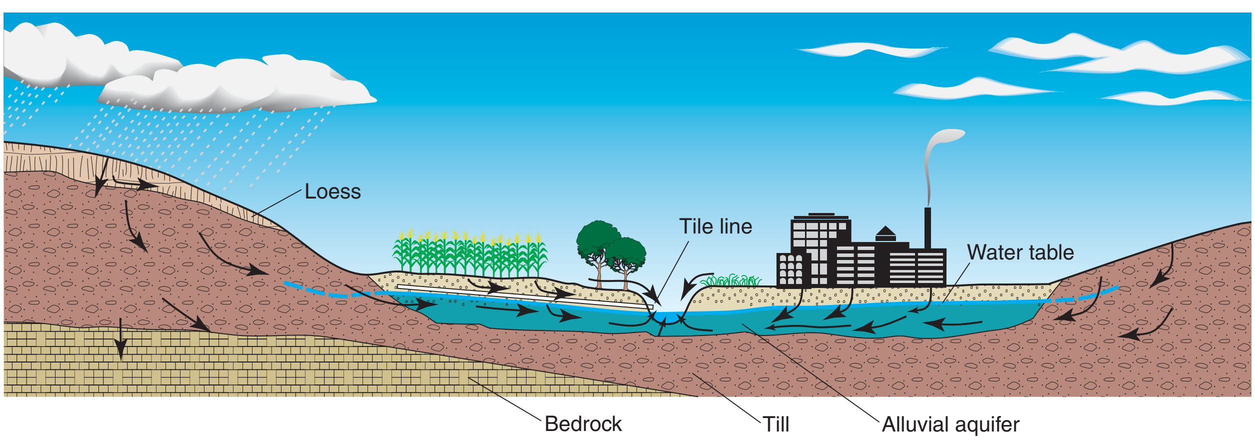


Figure 3. In the Eastern Iowa Basins, water originating from precipitation flows overland or through loess, till, and alluvial deposits to nearby streams. Areas with high water tables and poor natural drainage have commonly been artificially drained with tile lines. (Graphic created by Suzanne Roberts, U.S. Geological Survey.)

Surface Water

Excess precipitation that does not infiltrate into the soil or evaporate runs off to the streams (fig. 3). Generally, poorly permeable till soils typical of the Des Moines Lobe and steeper slopes typical of the Southern Iowa Drift Plain generate greater overland flow than the moderately well drained loess soils and gentle slopes typical of the Iowa Surface. Overland flow to streams is slowed or reduced by grass, perennials, shrubs, and trees (riparian buffers) where present near streambanks. Runoff to streams averages about 25 percent of the annual precipitation and ranges from less than 7 inches per year in the northern part of the Study Unit to about 9 inches per year in the southeastern part. Overland flow and ground-water discharge are the major sources of streamflow. However, tile lines may be an important source to streams during base flow in areas where they have been installed to remove standing water from surface depressions and to lower the water table.

Long-term yearly discharge from the Eastern Iowa Basins Study Unit averages about 9.2 million acre-feet. The overall increase in rainfall from 1996 to 1998 was reflected in the substantial increase in yearly stream discharge (fig. 4). Yearly discharge from the Eastern Iowa Basins increased from about 8.6 million acre-feet in 1996 to almost 13.8 million acre-feet in 1998. Yearly discharge was not uniform in the major basins. Discharge from the Wapsipinicon and Iowa River Basins increased in 1997 and 1998, and the discharge from the Skunk River Basin decreased from 1996 to 1998.

Ground Water

Water from rainfall infiltrates through the soil and, depending on whether permeable sand, gravel, and fractured bedrock are present, may continue to move to the deeper aquifers (fig. 3). If low-permeability clay or shale lies below the unconsolidated surficial materials, water may move laterally to a nearby stream.

Alluvial material that has been deposited by rivers and streams commonly consists of sand and gravel layers that store and transmit water readily. The alluvial aquifers (fig. 5) are the most frequently used source of ground water in the Eastern Iowa Basins because they are near land surface and can supply large amounts of water. The same properties (shallow depth and permeable material) that make alluvial aquifers excellent sources of water also make the alluvial aquifers susceptible to contamination from surface activities.

Two additional surficial deposits, not assessed during this study, provide water for domestic and municipal supplies. Sand and gravel deposits in low-permeability glacial till generally yield small quantities of water that are used mostly for rural domestic and stock supplies. Also, deep sand and

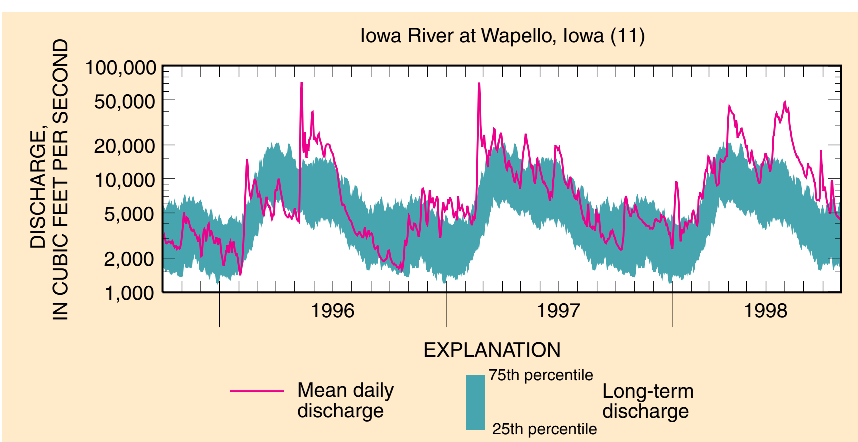


Figure 4. Stream discharge in the Eastern Iowa Basins ranged from below normal in 1996 to near normal in 1997 and above normal in 1998 (site number in parentheses; see site map in “Study Unit Design” section).

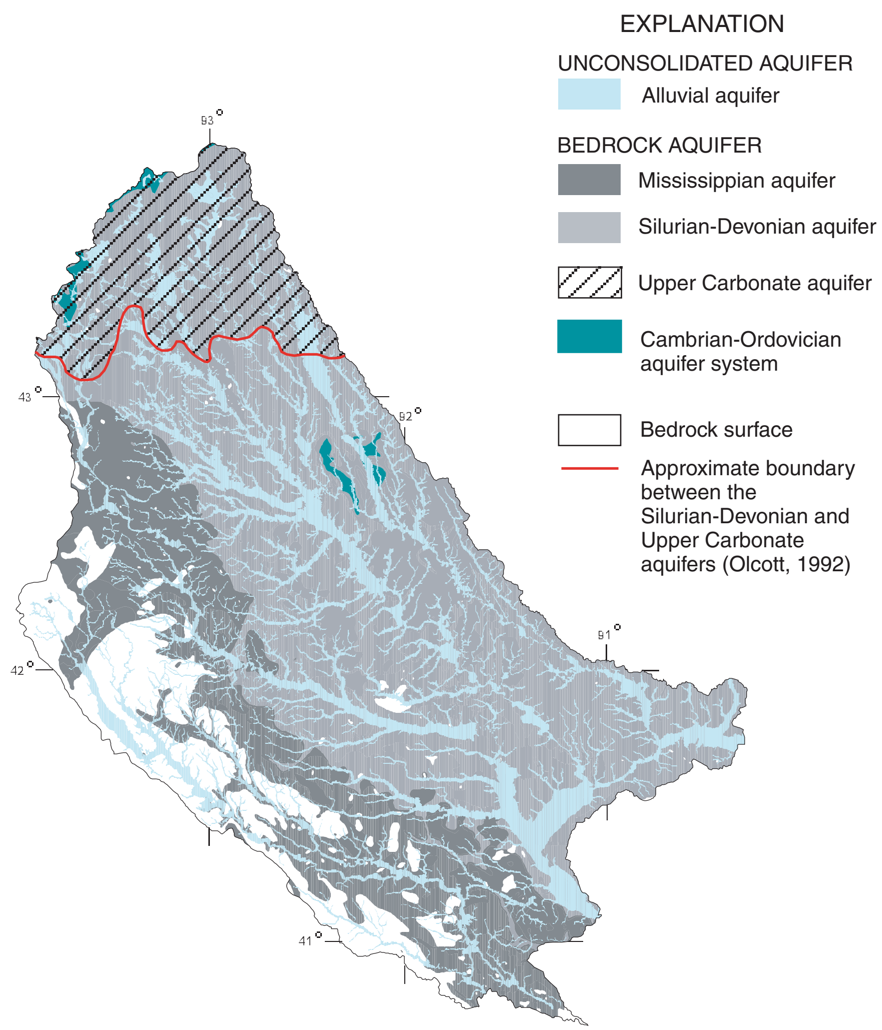


Figure 5. Several major bedrock and unconsolidated aquifers are used as sources of water for domestic, municipal, and industrial supplies. Only the most heavily used aquifers, the Silurian-Devonian and Upper Carbonate aquifers and the alluvial aquifers, were sampled.

gravel deposited in bedrock valleys before the last glacial advance is an important source of water in parts of the Eastern Iowa Basins.

Rock formations (bedrock) generally underlie the clay, silt, sand, and gravel surficial materials and can provide water for use. Bedrock aquifers are generally deep and are protected from surficial contamination. However, in areas such as the Iowan Karst, bedrock is exposed or is covered by very thin unconsolidated deposits and is susceptible to contamination from urban and agricultural land uses.

The most extensively used bedrock aquifers are the Silurian-Devonian and Upper Carbonate aquifers. The Silurian-Devonian and Upper Carbonate aquifers consist mainly of limestone and dolomite with locally interbedded shale and evaporite beds. Bedrock aquifers that are used as a source of water in the Study Unit but were not evaluated during this study are the Mississippian aquifer and the Cambrian-Ordovician aquifer system.

Nutrients in Ground Water and Streams

Two naturally occurring nutrients, nitrogen and phosphorus, commonly are applied in the form of fertilizers and manure in agricultural areas to increase the yield of crops and as fertilizer in cities and towns to enhance the appearance of residential lawns, city parks, and golf courses. Nitrogen and phosphorus also are commonly discharged from wastewater-treatment facilities. Nutrients that are not used by plants or attached to soil particles can move to shallow ground water or can be washed into nearby streams during intense rains. Runoff from rainfall and ground-water inflow can transport excess nutrients to streams, causing algal blooms that deplete oxygen for fish and other aquatic organisms. High concentrations of nitrogen in the form of nitrate may make untreated water unsuitable for human consumption. The USEPA has established a Maximum Contaminant Level (MCL) of 10 mg/L (milligrams per liter) for nitrate as nitrogen in drinking water (U.S. Environmental Protection Agency, 1996). High concentrations of nitrogen in the form of ammonia may kill fish and other aquatic organisms. To minimize algal growth in streams and reservoirs, a total phosphorus concentration of 0.10 mg/L or less has been recommended by the USEPA (1986).

Nutrients in Ground Water

Nitrogen and phosphorus are prevalent in ground water. Nitrogen readily moves from the land surface to ground water in the shallow alluvial aquifers but not as readily to most parts of the deeper Silurian-Devonian and Upper Carbonate bedrock aquifers in the Eastern Iowa Basins. Nitrogen, in the form of nitrate and ammonia, and dissolved phosphorus were detected in more than 65 percent of 124 ground-water samples. Nitrate concentrations were significantly higher in the shallow alluvial aquifers, which have been identified as being susceptible to contamination (Hoyer and Hallberg, 1991), than in the Silurian-Devonian and Upper Carbonate bedrock aquifers (fig. 6). Nitrate concentrations in water samples from monitoring wells screened near the water table in urban areas were higher than concentrations in samples from domestic wells, which generally are screened deeper in the aquifers.

Human and natural factors affect movement of nutrients to ground water. Downward movement of water containing nitrogen and phosphorus is slowed by fine-grained materials overlying the aquifers. The presence of clay in the soil and in the shallow subsurface and low-permeability rocks, such as shale, can slow ground-water infiltration rates and limit the amount of nutrients at depth. Surficial contamination most affects water near the top of the alluvial aquifers where the clay layer above the water table is thin or nonexistent (see fig. 8, p. 8).

In the Silurian-Devonian and Upper Carbonate aquifers, ground-water ages (determined by analysis of tritium concentrations) were significantly younger and nitrate concentrations were significantly higher in samples from areas where an overlying low-permeability shale layer was absent or where less than 100 feet of unconsolidated deposits overlies the aquifer (Savoca and others, 1999). These two results indicate that longer flow paths (deeper sample depth and thicker clay layer) increase opportunities for sorption, degradation, and dispersion and may contribute to decreases in nutrient concentrations with depth. Alternatively, water deeper in the aquifer may have infiltrated in years when fertilizer use was not as prevalent.

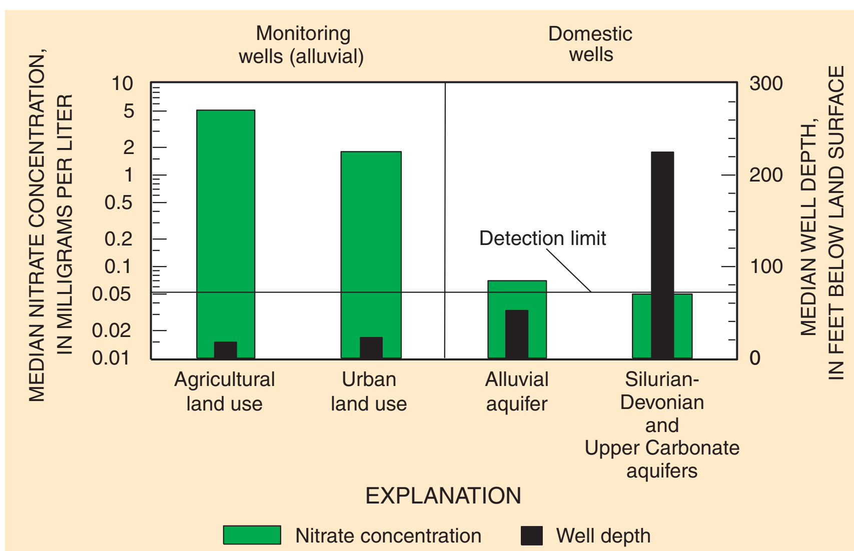
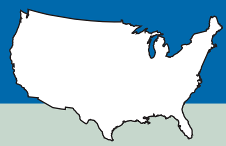
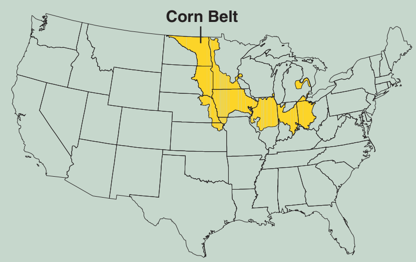


Figure 6. The shallowest ground water is most heavily affected by current land-use practices. Agricultural practices result in higher levels of nitrate in ground water than urban activities.



NUTRIENT CONCENTRATIONS IN STREAMS WERE AMONG THE HIGHEST IN THE NATION



Concentrations of nitrate and total phosphorus in streams in Eastern Iowa Basins rank among the highest in the Nation (fig. 7). The median discharge-weighted nitrate concentrations also were significantly greater in Eastern Iowa Basins streams than in streams sampled elsewhere in the Corn Belt and Northern Great Plains ecoregion (Omernik, 2000)—an area of similar climate, topography, regional geology and soils, and broad land-use patterns. Overall, total nitrogen concentrations were similar to the streams sampled in Illinois and to an agricultural stream sampled in southern Minnesota. Nitrate concentrations were in the upper 25th percentile nationally for 9 of 11 Basic Fixed Sites. The defined reference site (Wapsipinicon River near Tripoli) and the site on the stream draining the Iowan Karst landform (Flood Creek near Powersville) were within the middle 50 percent nationally. Concentrations of total phosphorus ranged from moderate to high in relation to other streams sampled in the United States. Average discharge-weighted total phosphorus concentrations at two sites (Old Mans Creek near Iowa City and Skunk River at Augusta) in the southern part of the Eastern Iowa Basins, where highly erodible loess soils cover most of the basins, were in the upper fifth percentile nationally.

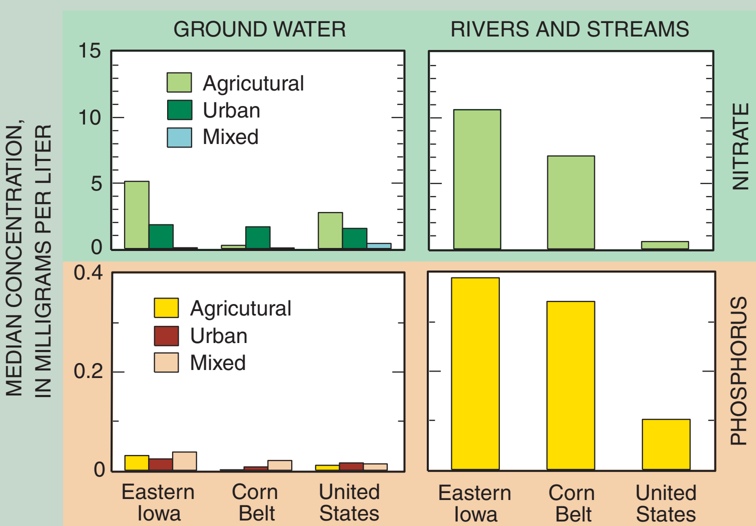


Figure 7. Nitrate and phosphorus concentrations in Eastern Iowa Basins streams and ground water are higher when compared with a wide variety of land uses across the Nation and when compared to similar land use in other parts of the Corn Belt. (Phosphorus in ground water as dissolved orthophosphorus and phosphorus in streams as total phosphorus)

Although substantially lower than in surface water, nitrate concentrations in the alluvial aquifers in agricultural areas in Eastern Iowa Basins are greater than those in ground water sampled elsewhere in the Corn Belt and the Nation. The alluvial aquifer is a relatively susceptible aquifer in contrast to aquifers within glacial till sampled in Illinois; therefore, the ranking of concentrations may not be directly comparable. However, nitrate concentrations in urban areas and in aquifers that serve as a source of water supply for municipal and domestic use in the Eastern Iowa Basins are comparable to those from the rest of the Nation. Dissolved phosphorus concentration in the alluvial aquifers in agricultural areas of Eastern Iowa Basins was greater than in ground water in the rest of the Nation. Increased susceptibility and greater fertilizer use may account for the higher phosphorus concentrations.

Natural processes may remove nitrogen from alluvial aquifers. The relation between nitrogen, dissolved oxygen, and organic carbon concentrations suggests that nitrogen is being biologically transformed and removed from the alluvial aquifers. Nitrate remaining after water moves through or around clay layers may be converted to nitrogen gas in a low-oxygen or oxygen-free environment in the presence of organic carbon. This process is called denitrification. Nitrate concentrations were significantly higher in alluvial ground water having dissolved oxygen concentrations

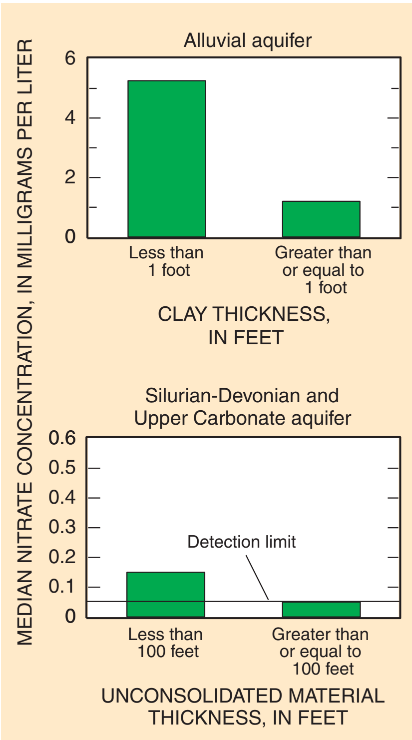


Figure 8. Overlying clay and other low-permeability material hinder movement of nitrate to ground water.

greater than 0.5 mg/L and were significantly lower in ground-water samples having increased dissolved organic carbon concentrations (Savoca and others, 2000). Denitrification may be an important natural process that reduces nitrate concentrations before water moves to ground-water supplies or is discharged to streams.

The type of land use affects shallow ground-water quality. Different uses, whether the land is used for agriculture, homes, business, or industry, are reflected in the nutrient concentrations in the ground water. Animal feeding operations can further affect water quality in areas with intensive row-crop agriculture (fig. 9). Nitrate was detected more frequently (94 percent of samples) and in greater concentrations (median of 5.1 mg/L) in shallow alluvial aquifers in agricultural areas than in urban areas. Nitrate was detected in 77 percent of samples at a median concentration of 1.8 mg/L from urban areas (fig. 6). Nitrate exceeded the USEPA MCL (10 mg/L as N) in 39 percent of samples from agricultural areas and in none of the samples from urban areas. Dissolved phosphorus concentrations tended to be higher in samples from agricultural areas (median of 0.03 mg/L) than urban areas (median of 0.01 mg/L); however, the difference was not statistically significant. The higher reliance on fertilizers in agricultural areas than in urban areas most likely contributed to the higher nitrate and phosphorus concentrations.

Ammonia is prevalent in shallow urban ground water. Dissolved ammonia concentrations were significantly higher in samples from urban areas than in samples from agricultural areas (fig. 9). The median dissolved ammonia concentration in samples from shallow urban ground water (0.025 mg/L) was more than twice the median concentration in samples from agricultural areas (0.010 mg/L). Anhydrous ammonia is used frequently as a nitrogen fertilizer for corn, but soil microbes quickly convert ammonia to nitrate.

Conditions in the alluvial aquifers (fig. 9) indicate that ammonia in shallow urban ground water originates, at least partly, from degradation of organic matter most likely derived from human activities. Substantial amounts of organic matter are available in the soil, silt, and clay above the aquifer and dissolved in water within the aquifer. Dissolved oxygen concentrations were significantly lower in urban areas than in agricultural areas. Microbial degradation of abundant organic matter would result in the decrease in dissolved oxygen concentrations and in the increase of dissolved ammonia concentrations in shallow ground water.

Nutrients move from ground water to streams by natural drainage and tile lines. At times, ground water contributes a substantial amount of nitrogen to streams in the Eastern Iowa Basins Study Unit. In most parts of the Study

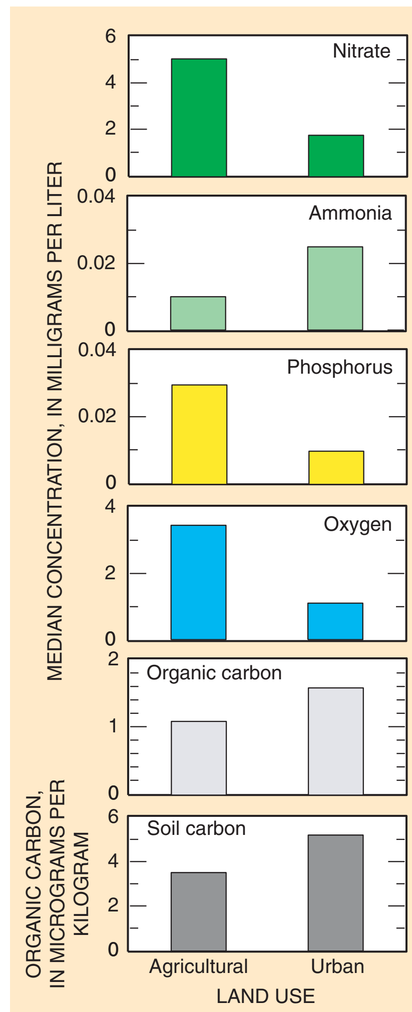


Figure 9. Agricultural and urban land uses contribute nitrogen to shallow alluvial aquifers. Conditions are suitable in urban areas for the formation of ammonia in the organic-enriched aquifers.

Unit, water naturally flows from alluvial aquifers to streams through the streambanks and streambeds. During high base flow in May 1998, nitrate concentrations in samples from 24 of 25 streams in the Eastern Iowa Basins were higher than 10 mg/L. In contrast, nitrate concentrations in these streams ranged from less than 0.05 to 8.3 mg/L during low base flow in August 1997. The high concentrations detected during the spring may be due to the increased ground-water inflow after fertilizer was applied and was readily available for transport.

Shallow tile lines have been installed to remove excess water from the land and to lower the water table in many parts of the Study Unit. These tile lines typically drain water from the upper part of the water table, which generally contains the highest nitrate concentrations to nearby streams. During the summer, the water table may decline below the tile lines due to decreased rainfall and increased evapotranspiration. Tile-line flow and nutrient transport then cease. For example, nitrate concentrations were consistently higher than 10 mg/L in tile-line discharge from April until the end of August when flow in this and other local tile lines ceased (fig. 10). After tile flow ceased, nitrate concentrations in the Iowa River decreased.

When tile flow ceases, streamflow originates from natural ground-water inflow, which traverses deeper and longer flow paths. Water that originates from deep in the alluvial aquifers contains low nitrate concentrations (see previous discussion) due to transformation in the aquifer or streambed and plant uptake as it passes beneath riparian buffers. These results are similar to those of previous studies (Cambardella and others, 1999; Soenksen, 1996) that documented the importance of tile-line discharge on stream-water quality.

Increased algal growth in late summer and early fall also can contribute to decreased nitrate concentrations in streams (Porter, 2000). Tile-line drainage is an important hydrologic factor that may serve to protect shallow ground water by removing contaminants before they move down into the aquifers; however, tile lines also may enhance the contamination of streams by short circuiting natural processes that remove nitrogen from ground water.

Nutrients in Streams

The concentrations of nutrients in a stream or river are the result of the interaction of human activities and natural factors in the basin. Human activities, agricultural and urban, generally increase the input of nitrogen and phosphorus into the basin, alter the land surface and drainage patterns (which may affect the amount and timing of rainfall runoff), and alter vegetation on the land and habitat in streams and rivers, resulting in a more rapid flushing of nutrients from the land and downstream in streams and rivers. Natural factors including the amount and timing of rainfall, soil types, and land-surface slope affect the amount of nitrogen and phosphorus washed off fields into nearby streams.

Nitrogen and phosphorus are almost always present in streams and rivers. Nitrate, the most common form of nitrogen in streams and rivers in the Eastern Iowa Basins, was present in more than 98 percent of the samples at concentrations of 0.05 mg/L or greater and was most frequently (80 percent of the samples) present in the range of 1 to 10 mg/L (fig. 11). Nitrate concentrations less than about 0.5 mg/L were generally associated with low streamflow in late summer when nitrogen inputs

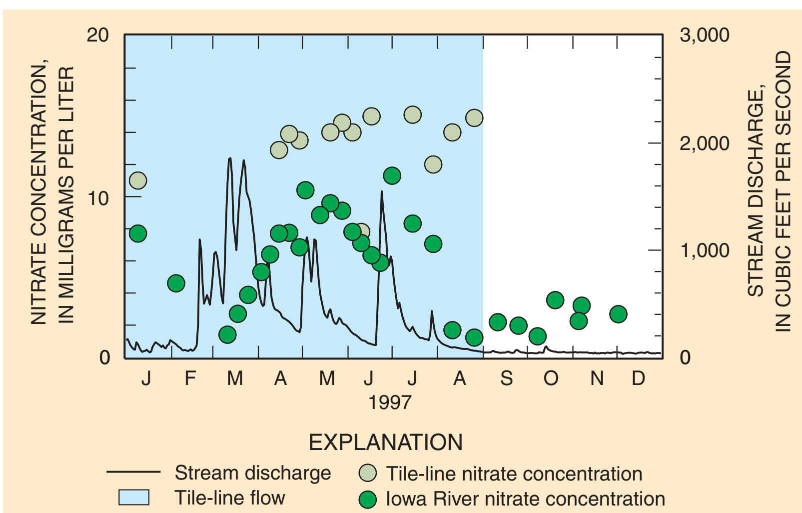


Figure 10. Tile lines can contribute substantial amounts of nitrate to streams and rivers. Nitrate concentrations in the Iowa River near Rowan decreased as tile-line discharge ceased.

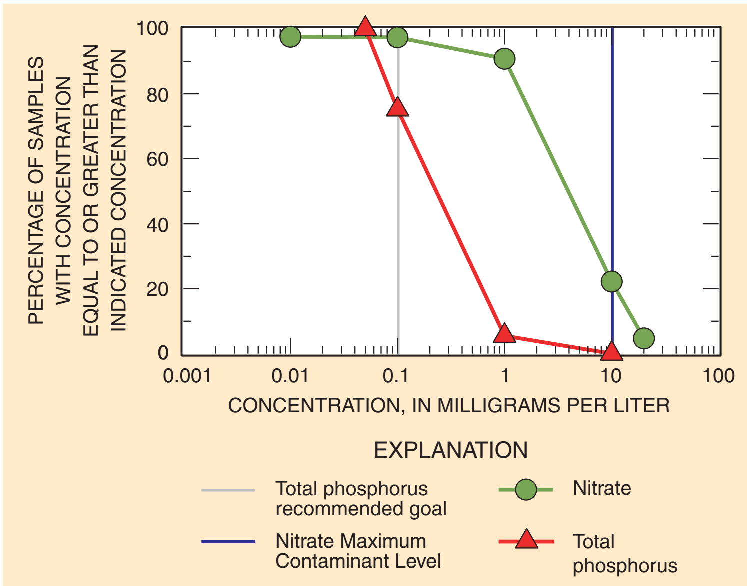


Figure 11. Nitrate concentrations in streams were most often in the range of 1 to 10 mg/L and equaled or exceeded the Maximum Contaminant Level in 22 percent of the samples. In contrast, total phosphorus concentrations equaled or exceeded the 0.1-mg/L goal for minimization of algal growth in 75 percent of the samples.

were low and algal uptake was high. About 22 percent of the samples (fig. 12) contained nitrate concentrations at or above the USEPA's drinking-water standard of 10 mg/L (U.S. Environmental Protection Agency, 1996).

Phosphorus, dissolved in the stream water and attached to sediment particles or organic compounds transported in the stream, was present in all samples. Total phosphorus concentrations exceeded the USEPA goal of 0.1 mg/L (U.S. Environmental Protection Agency, 1986) or less to minimize plant and algal growth about 75 percent of the time. Streams with large total phosphorus concentrations generally contained large suspended-sediment concentrations.

Landform and land use affect nitrogen and phosphorus concentrations. Nitrogen and phosphorus concentrations in streams differed among landform areas and with land use (fig. 12). Basins of the size investigated during this study where human activities are minimal (background) are not present in eastern Iowa and southern Minnesota. The Wapsipinicon River near Tripoli was identified as a reference site, however, because although agricultural land use constitutes more than 90 percent of the basin, substantial areas of riparian forests and wetlands remain. Samples from the reference site generally had the lowest median nutrient concentrations of any stream site studied. Median suspended-sediment concentrations also were the lowest. Biological indicators of water quality at the reference site were better than all other sites in the Study Unit. Extensive floodplain vegetation may decrease direct transport of nutrients from fields to the Wapsipinicon River, and extensively wooded banks on the nonchannelized river may decrease streambank erosion and enhance biological habitat.

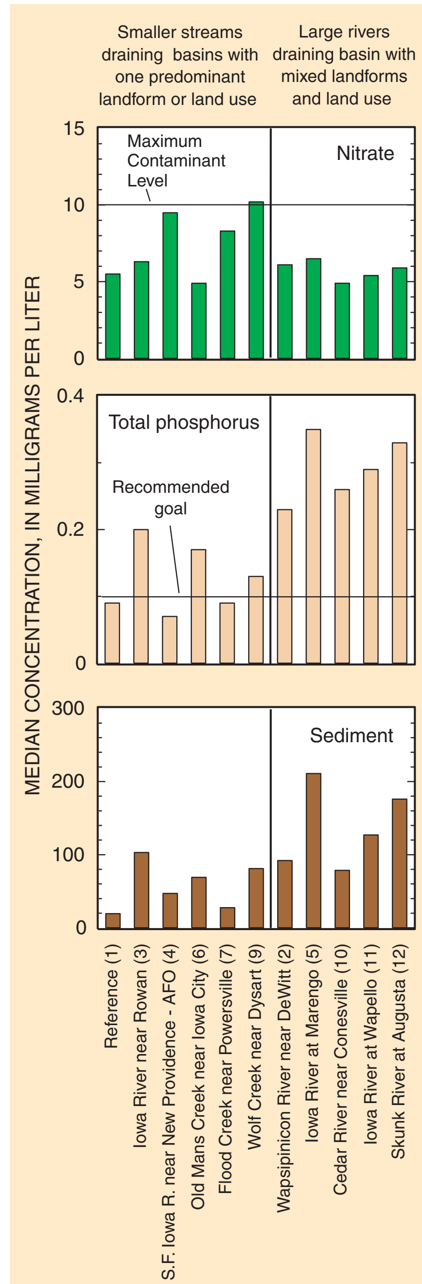


Figure 12. Nitrate concentrations generally were lower in large rivers than in smaller streams. In contrast, total phosphorus concentrations were greater in large rivers than in streams. (Site number in parentheses; see site map in Study Unit Design section. AFO is animal feeding operation.)

Median nitrate concentrations were highest in samples from Wolf Creek, a stream draining an Iowan Surface basin that has more than 80-percent row-crop agriculture, and in samples from the South Fork Iowa River, a stream draining a Des Moines Lobe basin that has concentrated animal-feeding operations (AFO). The median nitrate concentration in samples from Wolf Creek (10.2 mg/L) exceeded the 10-mg/L USEPA MCL. Algal status and biomass in Wolf Creek indicated degraded conditions (from a national perspective), and fish and invertebrate communities were dominated by species tolerant to nutrient and organic enrichment. Wolf Creek flows into the upper end of a reach of the Cedar River that has been listed on the 1998 USEPA Section 303(d) list (Iowa Department of Natural Resources, 2000) as an impaired water body. Wolf Creek may provide substantial amounts of nitrogen that contribute to the degradation of the Cedar River between Waterloo and Cedar Rapids.

Landform features affect phosphorus concentrations. Phosphorus and suspended-sediment concentrations were typically larger in streams that drain the Southern Iowa Drift Plain and the Des Moines Lobe than in other streams. The Southern Iowa Drift Plain typically has steeper slopes than the rest of the Study Unit and contains loess deposits that are easily eroded (Schwarz and Alexander, 1995). Many Des Moines Lobe streams have been extensively channelized; to a great extent, the streambanks and flood plains contain little riparian vegetation, resulting in a greater dominance of phytoplankton than benthic algae and relatively higher rates of stream metabolism that can influence dissolved-oxygen conditions during base-flow conditions (Porter, 2000).

Intensive row-crop agriculture contributes to greater nitrate concentration. The intensity of row-crop agriculture is partly responsible for the variability of nitrate concentrations in streams. Typically, streams in basins that have a higher percentage of corn and soybeans and less pasture, forest, and CRP (Conservation Reserve Program) acres had higher total nitrogen concentrations (fig. 13). However, large rivers in basins that had a slightly lower percentage of row crops and a slightly larger proportion of urban areas typically had higher total phosphorus concentrations. Large rivers generally contained higher suspended-sediment concentrations than streams, and most large potential point-source phosphorus contributors (large cites) are located on the large rivers.

Increased availability results in greater nutrient concentrations during the spring and early summer. Concentrations of nitrogen and phosphorus varied seasonally in streams in eastern Iowa (fig. 14). Median total dissolved nitrogen concentrations were highest in June (11.5 mg/L) when nitrogen is transported to streams and rivers by spring and early summer runoff from rainfall. Nitrogen probably originates from that accumulated in the soil following application of chemical fertilizers and manure during the spring and previous fall. Nitrate was the predominant form of nitrogen detected during this period. Total dissolved nitrogen concentrations in streams decreased through the summer as nitrogen was removed from the soil by plant uptake, runoff, and leaching to shallow ground

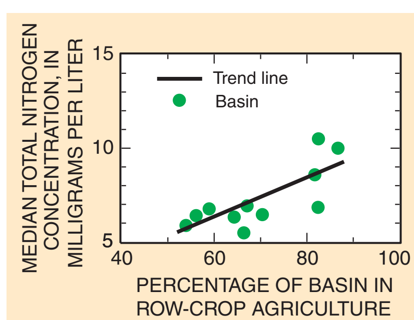


Figure 13. Streams draining basins that have higher percentages of pasture, grassland, and forests and less land planted in row crops tended to have lower nitrogen concentrations.

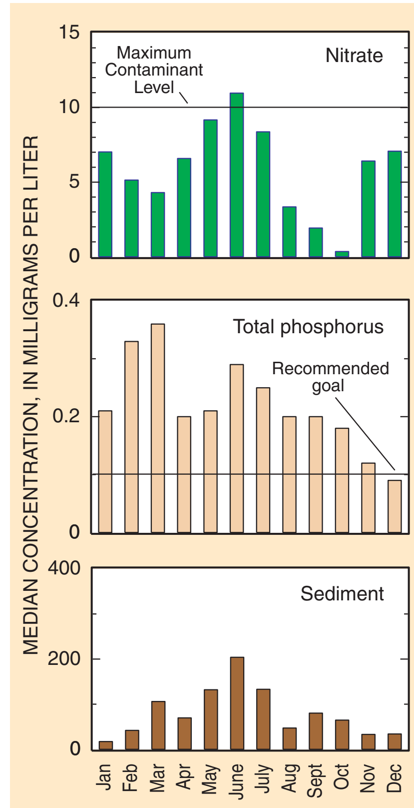


Figure 14. Nitrate concentrations that commonly increase to levels that exceed the Maximum Contaminant Level in June can decrease to levels below detection in October. Total phosphorus concentrations were rarely below the recommended goal for reduction of algal growth.

water. Algal and plant growth in the streams during low streamflow in late summer and early fall can result in increased uptake of dissolved nutrients (Porter, 2000). The combination of reduced source loading and instream processing results in lowest nitrate concentrations in October. Fall rains, in combination with fertilizer and manure applications, were associated with another rise in nitrogen concentrations beginning in November and peaking in January. Although nitrate remained the primary form of nitrogen, ammonia and organic nitrogen were more prevalent during the winter.

Runoff from agricultural and urban areas transports substantial amounts of phosphorus to streams, but the timing of peak phosphorus concentrations does not always correspond to peak nitrate concentrations. Phosphorus concentrations peak during periods of high runoff in early spring when substantial amounts of soil are eroded into the streams. The highest median total phosphorus concentrations occurred in February (0.33 mg/L) and March (0.36 mg/L) with a secondary peak in June (0.29 mg/L) (fig. 14). Maximum concentrations corresponded with early seasonal runoff from snowmelt or rainfall. Early summer rains produced runoff that accounted for a secondary peak in total phosphorus concentrations during June.

Transport of nutrients represent an economic loss and a potential environmental threat. The large amounts of nitrogen and phosphorus that are transported from the Study Unit by the Wapsipinicon, Cedar, Iowa, and Skunk Rivers represent an economic loss to farmers and an environmental concern for downstream water.

Nitrogen and phosphorus transported to the Mississippi River increased yearly from 1996 through 1998 (fig. 16). Increased streamflow was a major factor in the increased loads. The estimated mass of nitrogen (load) increased from about 106,000 tons in 1996 to more than 257,000 tons in 1998, and the estimated total phosphorus load increased from 7,500 tons in 1996 to 9,700 tons in 1998.

ANIMAL FEEDING OPERATIONS CONTRIBUTE ADDITIONAL NUTRIENTS TO STREAMS

The median nitrate concentration in samples from the South Fork of the Iowa River (9.5 mg/L) were significantly higher than those in samples from the Iowa River near Rowan (median of 6.3 mg/L), though both streams drain the same landform (Des Moines Lobe) and have similar crop patterns (greater then 80 percent row crops). In addition to row-crop agriculture, the basin of the South Fork Iowa River contains substantially more permitted animal feeding operations (AFO) (29) than the Iowa River Basin upstream from Rowan (8). The density of hogs (fig. 15) in the South Fork basin is more than twice that in the Iowa River Basin (Sorenson and others, 1999). The manure generated from AFOs is commonly applied on fields in substitution for chemical fertilizer. However, in areas where there is dense concentration of AFOs, sufficient land may not always be available to economically dispose of animal wastes, and the potential for overapplication exists. Excess nutrients seep into the ground water and are washed into nearby streams. About 1.8 times more nitrogen and about 2.5 times more phosphorus were transported by the South Fork Iowa River than by the Iowa River (fig. 15). The higher nitrate concentrations and the greater nitrogen and phosphorus yields from the South Fork Iowa River compared to the Iowa River near Rowan may indicate that a reduction in chemical fertilizer application equivalent to the increased manure application has not occurred in the South Fork Basin.

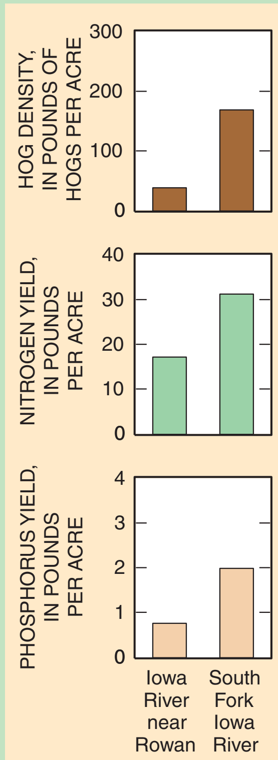


Figure 15. Large-scale hog production adds to the nitrogen and phosphorus in streams draining basins in the Des Moines Lobe landform. [Hog density data calculated from Iowa Department of Natural Resources (1999) waste-control facility permits.]

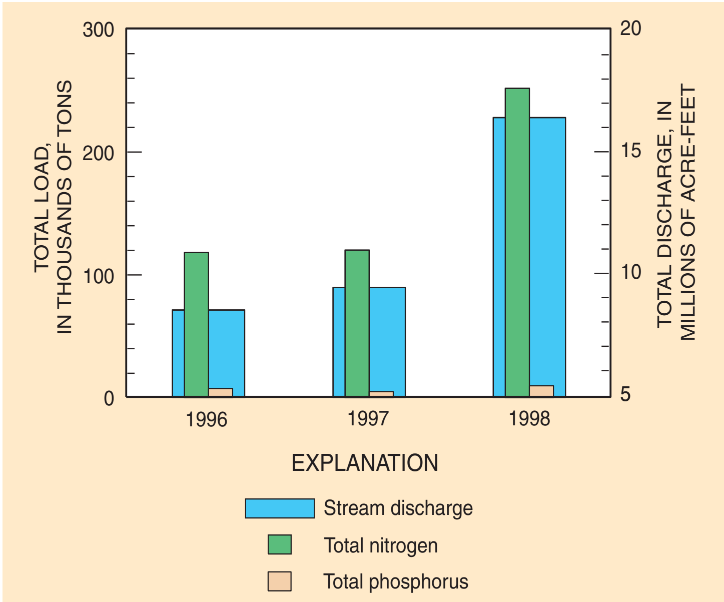


Figure 16. Increased streamflow from 1996 to 1998 resulted in larger amounts of nitrogen and phosphorus transported from the Study Unit to the Mississippi River.

Transport of nutrients from the Eastern Iowa Basins represents a potential loss in crop yield or the cost of additional fertilizer needed to compensate for that flushed from the fields. Nutrient loads transported from the Eastern Iowa Basins represent an average loss of 17 lb/acre/year of nitrogen and 1.2 lb/acre/year of phosphorus in 1996 and 42 lb/acre/year of nitrogen and 1.6 lb/acre/year of phosphorus in 1998.

Iowa, including the Eastern Iowa Basins, has been identified as a major source of nutrients (Goolsby and others, 1999) that contribute to eutrophication and hypoxia in the Gulf of Mexico (Rabalais, 1996). Alexander and others (2000) estimated that more than 90 percent of the nitrogen reaching the Mississippi River from the Eastern Iowa Basins is transported to the Gulf of Mexico.

Pesticides in Ground Water and Streams

Pesticides (herbicides and insecticides) are used extensively in agricultural and urban settings in the Eastern Iowa Basins to control unwanted vegetation and insects. Triazine (atrazine and cyanazine) and chloroacetanilide (alachlor and metolachlor) herbicides were the most extensively used pesticides during 1996–98. However, in 1994, acetochlor, a herbicide conditionally registered by the USEPA, began to replace alachlor. In 1998, acetochlor use exceeded all other herbicides in Iowa (U.S. Department of Agriculture, 1999). Other classes of low-use herbicides (for example, sufonylurea and imidozolinone herbicides) also had become more popular. Genetically altered corn and soybeans that are resistant to glyphosate and genetically altered “Bt corn" that contains the genes allowing corn to produce compounds toxic to damaging insects also were beginning to change pesticide-use patterns. Although urban pesticide-use data were not available, herbicides commonly are used on lawns, golf courses, and road rights-of-way for weed control, and a wide range of insecticides are used for insect control.

Transport of pesticides from the site of application is dependent on the persistence of the compound, its solubility in water, and its tendency to adsorb to soil particles. Pesticide compounds break down at various rates due to biological and chemical processes. Pesticides can be broken down in the soil by bacteria and fungi and nonaffected plants and in streams by microorganisms, algae, and aquatic plants. The older organochlorine pesticides, most of which have been banned (for example, DDT) strongly attach to soil particles and are transported to streams primarily with sediment. In contrast, many herbicides commonly used in the 1990’s (for example, atrazine) are relatively soluble and are transported almost exclusively dissolved in water. Water is the primary mechanism by which most pesticides and their breakdown products (degradates) are leached to ground water. Water transports pesticides and their degradates to streams by overland flow, tile drains, and ground-water inflow.

PESTICIDE CONCENTRATIONS RANK HIGHER IN GROUND WATER THAN IN STREAMS AND RIVERS

Herbicide and insecticide concentrations in streams do not rank among the highest 25th percentile nationally (fig. 17) even though use in the Eastern Iowa Basins is high. Herbicide concentrations rank in the middle 50 percent nationally and in the middle one-third in the Corn Belt. Insecticide concentrations are among the lowest in the Corn Belt and Nation. Reasons for lower pesticide concentrations in the Eastern Iowa Basins compared to other parts of the Nation are not entirely clear but may include these: (1) although pesticide use is high in Eastern Iowa Basins it may be higher in other corn, cotton, and other crop-growing areas of the Nation and (2) soils in Eastern Iowa Basins may be relatively conducive to leaching to ground water or conditions are favorable for breakdown of the pesticides.

In contrast, herbicide and insecticide concentrations in the alluvial aquifers in Eastern Iowa Basins are among the highest 25th percentile in the Corn Belt and Nation (fig. 17). Water in these aquifers has infiltrated within the last 20 years when the use of the analyzed pesticides was the greatest. Because water from the Silurian-Devonian and Upper Carbonate aquifers is generally deeper and has infiltrated before pesticides were commonly used, pesticide concentrations from these aquifers generally were among the lowest in the Nation.

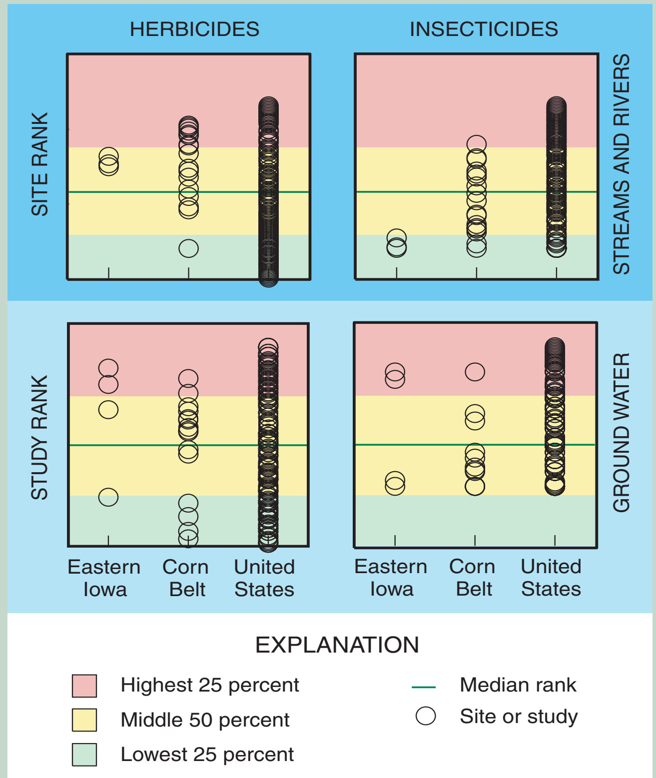


Figure 17. Although pesticides are heavily used, concentrations in the Eastern Iowa Basins streams are not among the highest in the Nation or the Corn Belt. The vulnerability of the alluvial aquifers to contamination is seen in pesticide concentrations in ground-water samples that are among the highest in the Nation.

Pesticides in Ground Water

Herbicides are prevalent in the shallow alluvial aquifers. Herbicides are prevalent in the shallow alluvial aquifers but are not common in the deeper Silurian-Devonian and Upper Carbonate bedrock aquifers in the Eastern Iowa Basins. Atrazine and metolachlor were the most frequently detected herbicides in the alluvial aquifers and the Silurian-Devonian and Upper Carbonate aquifers. Atrazine was detected in more than 50 percent of the alluvial aquifer samples and in 18 percent of the Silurian-Devonian and Upper Carbonate aquifer samples. Metolachlor was detected in 20 percent of the alluvial samples and in 12 percent of the Silurian-Devonian and Upper Carbonate samples. Acetochlor was detected in slightly less than 2 percent of the alluvial aquifer samples but at concentrations less than 0.2 µg/L, which is the concentration of concern for conditional registration. Acetochlor was not detected in samples from the Silurian-Devonian and Upper Carbonate aquifers.

Pesticide degradates commonly constitute the majority of the pesticide mass analyzed. Many of the detected pesticides and pesticide degradates have no established drinking-water standard or aquatic-life criteria, and the potential for these compounds to affect humans or aquatic organisms is unknown. Alachlor ethanesulfonic acid (ESA), atrazine, and metolachlor ESA were detected in more than 30 percent of samples from shallow alluvial (fig. 18) and deep bedrock aquifers.

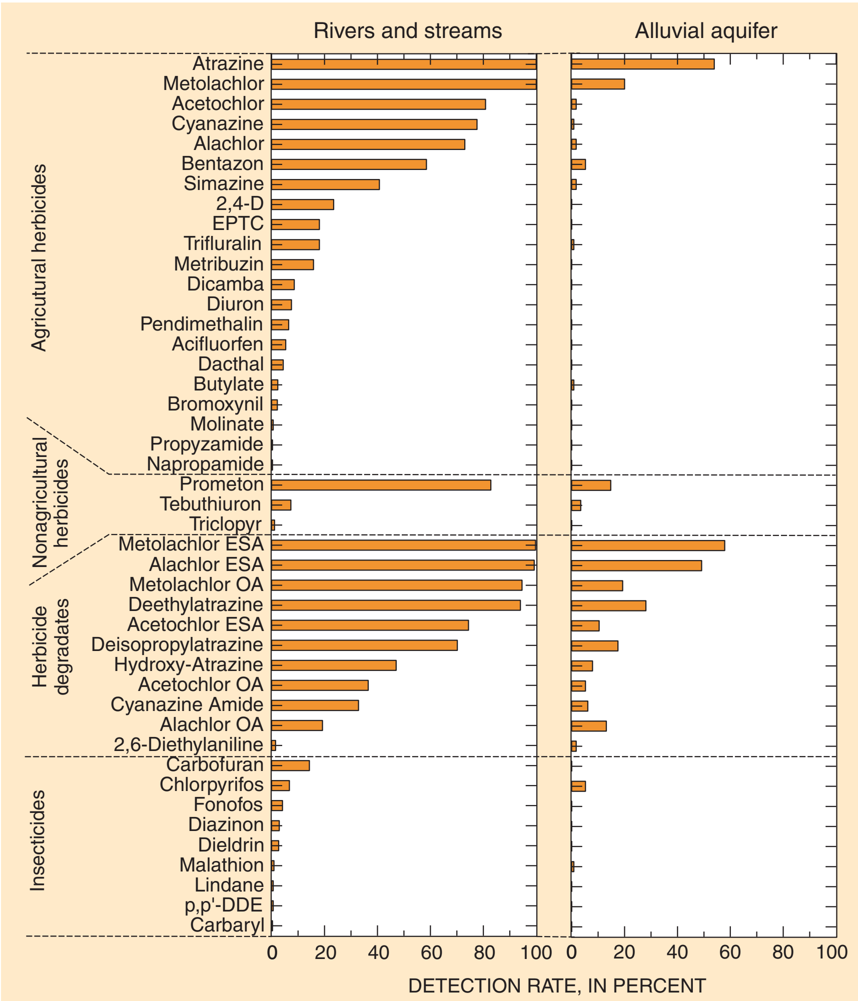


Figure 18. The pesticide compounds present in streams and rivers and the alluvial aquifers, which are hydraulically connected, were similar but were detected less frequently in ground water. Agricultural herbicides and their degradates were most frequently detected.

Agricultural and urban applications have resulted in sporadic low levels of insecticide contamination in the alluvial aquifers. Chlorpyrifos, an insecticide that was recently reevaluated by the USEPA for safety as part of the Food Quality Protection Act (U.S. Environmental Protection Agency, 2000b), was detected in about 7 percent of the urban land-use samples and about 13 percent of the agricultural land-use samples. The maximum concentration in urban areas (0.005 µg/L) was about four times lower than the maximum concentration in agricultural areas (0.021 µg/L). Malathion, an insecticide also currently (2000) under USEPA review, was detected in one sample from an urban land-use well.

Pesticides do not occur everywhere in the Study Unit, and when they do occur, concentrations can be highly variable. This variability in occurrence and concentration of various pesticide compounds in ground water is probably associated with several factors including the presence of overlying protective layers and land-use practices.

Clay and shale materials hinder movement of pesticides to aquifers. Clay and shale materials hinder movement of pesticides by slowing the movement of water containing pesticides to underlying aquifers. In some instances, water that has infiltrated the ground during the last 40 years when many of the studied compounds were used has not yet reached the deeper parts of the alluvial and bedrock aquifers. The age of the ground water was significantly younger and pesticide concentrations were significantly higher in samples from areas where an overlying bedrock confining unit was absent or where less than 100 feet of unconsolidated deposits overlies the Silurian-Devonian and Upper Carbonate aquifers. Water is most affected by surficial contamination near the top of alluvial aquifers where an overlying clay layer is thin or absent. Triazine pesticides and degradate concentrations were significantly higher in samples from wells in areas with a thin clay layer above the screened interval than those from wells in areas with thick overlying clay layers. Concentrations decreased with increasing depth in the alluvial aquifers. As with nitrate, these two results indicate that longer and slower flow paths (deeper sample and thicker clay layer) increase opportunities for sorption, degradation, and dispersion of pesticides and may contribute to decreases in pesticide concentrations with depth.

WHAT IS A PESTICIDE DEGRADATE?

Pesticides released into the environment break down into intermediate compounds and, over time, into their constituent molecules (fig. 19). The intermediate compounds are pesticide degradates that may be short-lived or persist for years. The occurrence of atrazine degradates in ground water and surface water is relatively well known, but the occurrence of alachlor, acetochlor, and metolachlor degradates in Iowa have only recently been investigated (Kalkhoff and others, 1998; Kolpin and others, 1997). Little is known about their possible effects on human health and aquatic life (Heydens and others, 2000; Stamper and Tuovinen, 1998). The occurrence and distribution of several common degradates of atrazine, alachlor, acetochlor, cyanazine, and metolachlor were documented in the Eastern Iowa Basins to develop a better understanding of the fate and transport of these compounds and their possible effect on the environment. These compounds generally are the products of the first step in the breakdown of the most commonly used herbicides. Breakdown occurs in the soil but also can take place in plants and in ground water and streams. Modification of a side carbon chain (atrazine degradation) or the replacement of the halogen (chlorine) with a sulfonic acid or carboxilic acid (acetochlor, alachlor, metolachlor degradation) is commonly the first step in the breakdown of these herbicides. This first step represents a small molecular change that may affect the toxicity, solubility, and persistence of the resulting degradate.

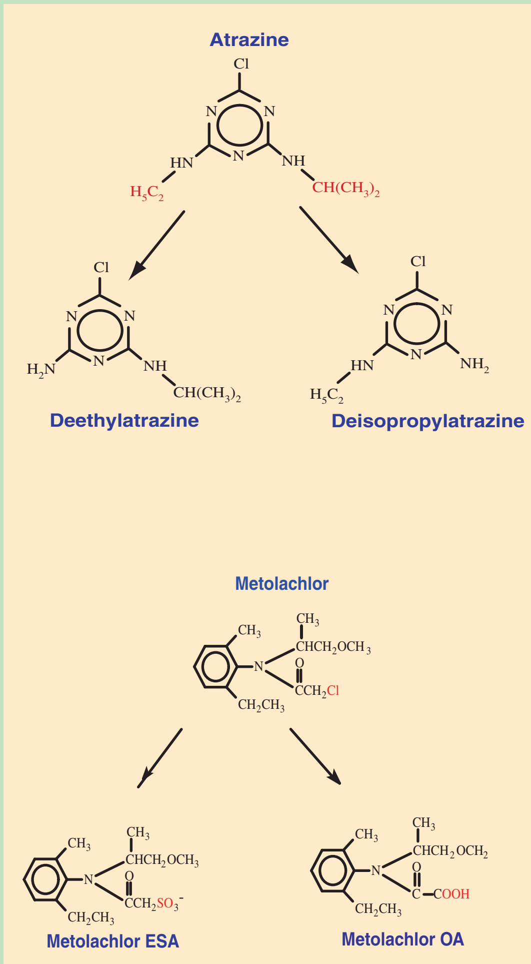


Figure 19. Small molecular changes (shown in red) occur during the initial breakdown of atrazine and metolachlor.

Pesticides are present in alluvial aquifers both in urban and agricultural areas. Pesticides were prevalent in the shallow alluvial aquifers both in agricultural and urban areas (fig. 20). Pesticides were detected in 84 percent of the samples from agricultural areas and in 70 percent of the samples from urban areas. Atrazine and metolachlor were the most frequently detected pesticides in samples from agricultural areas; atrazine and prometon were the most frequently detected pesticides in samples from urban areas. None of the concentrations exceeded USEPA MCLs, but many pesticides do not have MCLs.

Samples from alluvial aquifers in agricultural areas contained an average total pesticide concentration (1.3 µg/L) that was more than seven times the concentration in samples from urban wells (0.17 µg/L). Although total pesticide concentrations were higher in samples from agricultural areas, more compounds were detected in samples from urban areas. Seventeen compounds were detected in samples from urban areas compared to 12 compounds detected in samples from agricultural areas. Herbicide degradates were detected in 94 percent of samples from agricultural areas and 53 percent of the samples from urban areas. Alachlor ESA, metolachlor ESA, and metolachlor oxanilic acid (OA) were the most frequently detected degradates in samples from both agricultural and urban areas; deethylatrazine and deisoproplyatrazine were detected frequently in agricultural areas.

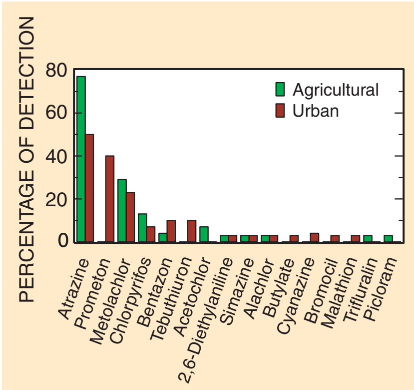


Figure 20. Pesticides were frequently detected in the alluvial aquifers in both agricultural and urban areas. Although the total concentrations of pesticides were higher in agricultural areas than in urban areas, more compounds were detected in urban than in agricultural areas.

Pesticides in Streams

The most commonly used herbicides were the most frequently detected. Atrazine and metolachlor, the two most commonly used herbicides in Iowa for row-crop agriculture during 1996–98, were detected in all stream samples (fig. 18). Acetochlor, alachlor, and cyanazine were detected in more than 70 percent of the samples. Most atrazine concentrations (76 percent) exceeded 0.1 µg/L with almost 60 percent of the samples in the 0.1 to 1.0 µg/L range (fig. 21). About 10 percent of the samples exceeded the atrazine MCL level of 3.0 µg/L. Almost half of the samples had metolachlor concentrations in the range from 0.1 to 1.0 µg/L (fig. 21). Other less frequently detected pesticides were carbofuran, 2,4-D, dicamba, EPTC, metribuzin, and trifluralin; these were applied in Iowa at a rate of only 0.6 to 30 percent of the amount applied for atrazine (Sands and Holden, 1996).

Acetochlor, a conditionally registered herbicide that is intended to replace a number of other commonly used herbicides, was frequently detected but most times (75 percent) at concentrations less than 0.1 µg/L. Acetochlor concentrations did not exceed the 2.0-µg/L annual mean concentration registration requirement at any site but did exceed this level in about 3 percent of the individual samples. The maximum concentration (10.6 µg/L) measured during the study exceeded the level that would trigger requirements for biweekly sampling for water-supply systems (U.S. Environmental Protection Agency, 1994).

Few nonagricultural herbicide compounds were detected. Many pesticides are used both in agricultural and urban settings, but only three herbicides used almost exclusively in non-row-crop agriculture and urban settings (prometon, tebuthiuron, and triclopyr) were present in streams in eastern Iowa and southern Minnesota from 1996 through 1998 (fig. 18). Prometon, a herbicide used for weed control around buildings, fence rows, and under asphalt, was present at very low concentrations (less than 0.1 µg/L) in more than 80 percent of the samples. Prometon is extremely persistent (half-life of hundreds to thousands of days), which may explain the relatively high detection rate relative to its low use. Tebuthiuron, used on road rights-of-way and industrial sites, was detected in 7 percent of the samples. Triclopyr, used on road rights-of-way, industrial sites, and turf grass, was detected in 1 percent of the samples.

Insecticides were detected mainly during the summer. A number of insecticides that have been identified as posing a high risk to aquatic invertebrates were detected in streams from May through September, the months when most application normally occurs (fig. 22). Carbofuran was the most frequently detected insecticide (16 percent of all samples). Although detected in less than 20 percent of all samples, carbofu-

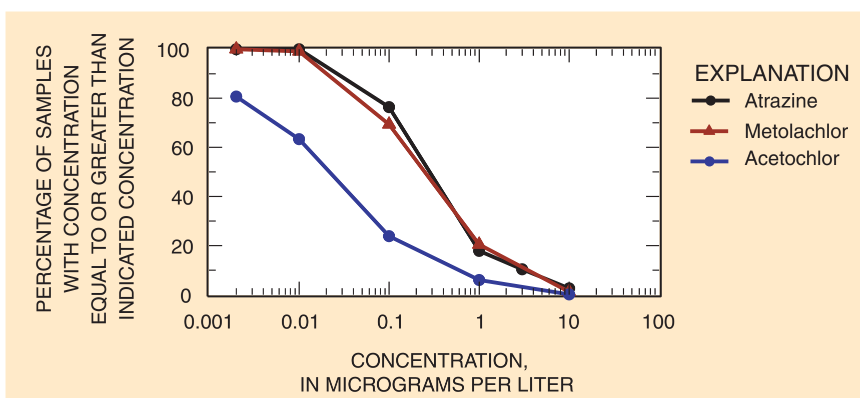


Figure 21. Atrazine and metolachlor were present in more than 50 percent of the samples from rivers and streams at concentrations between 0.1 and 1.0 µg/L. In contrast, acetochlor was present in 76 percent of the samples at concentrations less than 0.1 µg/L.

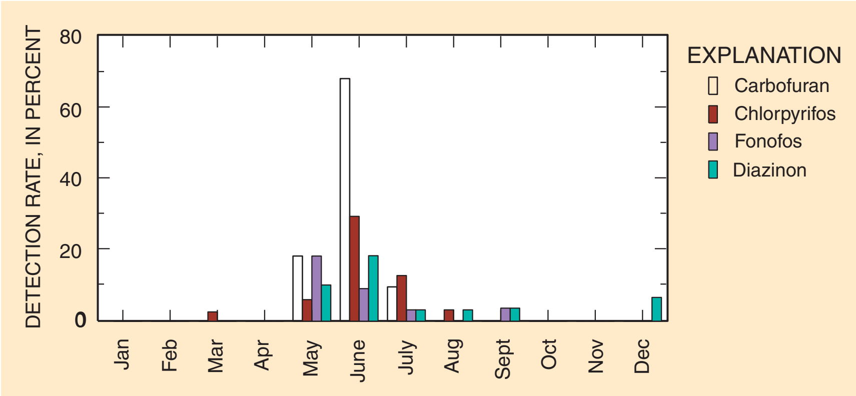


Figure 22. Insecticides were prevalent in streams only during the late spring and summer. Carbofuran and chlorpyrifos were the most frequently detected insecticides.

ran was detected in 68 percent of the samples collected in June. When present, carbofuran concentrations generally were less than 0.80 µg/L. Chlorpyrifos was detected in about 7 percent of the samples. As with the other insecticides, chlorpyrifos was detected most frequently in June (about 30 percent of the samples). The highest concentration was 0.06 µg/L. Malathion was detected in only three samples in spring and early summer at concentrations that ranged from 0.023 to 0.078 µg/L. Insecticides were detected more frequently in streams than in shallow ground water in the alluvial aquifers. Lower use relative to the herbicides, short half-life, and application during periods of reduced runoff may account for the overall low detection rate and low concentrations of insecticides in rivers and streams.

Pesticide degradates constitute the majority of the pesticide compounds in streams. The pesticide degradate compounds were some of the most frequently detected pesticide compounds in streams (fig. 18) and on average constituted the majority of the pesticide mass in water samples. Acetochlor ESA, alachlor ESA, metolachlor ESA, and metolachlor OA were detected in more than 75 percent of the samples. The degradates were detected much more frequently than their parent compounds with the exception of atrazine and two of its degradates—deethylatrazine and deisopropylatrazine (fig. 18).

On average, approximately 83 percent of the total pesticide mass (parent compounds and degradates) can be accounted for by 10 common degradates of acetochlor, alachlor, atrazine, cyanazine, and metolachlor. Concentrations of acetochlor ESA, alachlor ESA, and metolachlor ESA commonly were more than 10 times higher than their parent compounds. Although herbicide degradates frequently occur in substantial concentrations in streams, only limited research has been conducted on the acute and chronic human and environmental effects of these compounds (Heydens and others, 2000).

The occurrence of degradates and the ratio of degradate to parent compound were substantially different for the triazine (atrazine and cyanazine) than the chloroacetanilide (acetochlor, alachlor, and metolachlor) compounds. Concentrations of the triazine degradates tended to follow the pattern of the parent compounds—highest concentrations during the early summer followed by decreasing concentrations during the late summer and fall (fig. 23). However, concentrations of the triazine degradates were lower than their parent compounds except in the fall and winter when they were slightly higher. In contrast, the ESA and OA degradates of alachlor, acetochlor, and metolachlor were present in higher concentrations than their parent compounds throughout the year.

Occurrence of pesticides are related to landform type. The triazine herbicides—atrazine and cyanazine—and their degradates were present in significantly higher concentrations in streams draining soils dominated by windblown

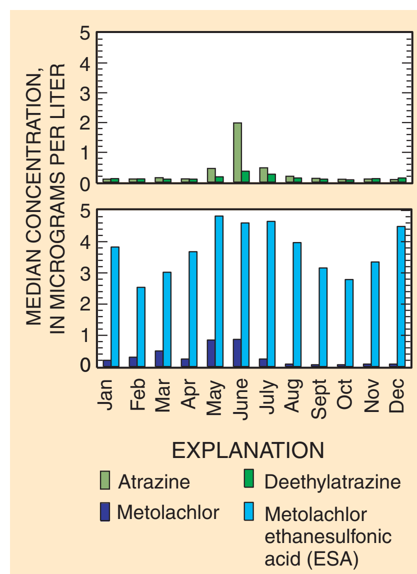


Figure 23. Pesticides and their degradates are readily available for transport to streams and rivers in late spring and early summer after application. A common metolachlor degradate persists at higher concentrations than a common atrazine degradate throughout the year.

Multiple Pesticide Compounds Occur More Frequently in Streams Than in Ground Water

The use of a wide variety of pesticides in the Eastern Iowa Basins is reflected by the presence of multiple compounds in streams and ground water. Two or more compounds were detected in every sample, and five or more compounds were detected in more than 80 percent of the stream samples (fig. 24). As many as 16 pesticide compounds were detected in a single stream sample. In contrast, 2 or more compounds were detected in only 17 percent and 5 or more pesticides in less than 2 percent of the ground-water samples.

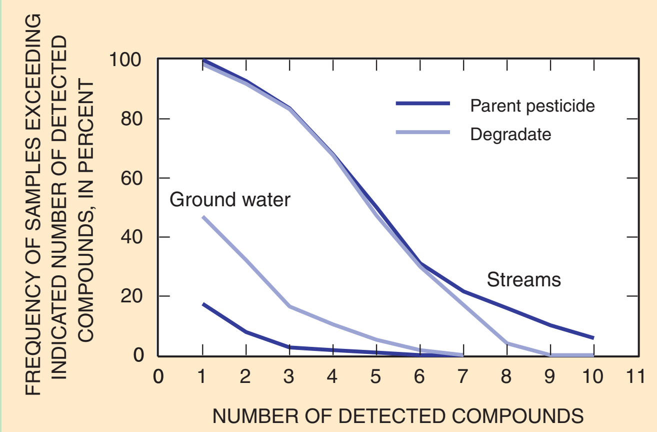


Figure 24. More than one pesticide compound was always present and more than five compounds were detected in about 80 percent of the stream samples. Multiple degradates were more common than multiple parent compounds in ground water.

Multiple degradates were much more frequently detected than multiple parent compounds in ground water. Many pesticide compounds attach to soil particles and are not readily leached to the ground water. However, the pesticide degradates sampled are generally more water soluble and once formed in the soil may move readily to the shallow ground water. Also, several degradates may form from each pesticide, accounting for additional degradate compounds.

The importance of multiple pesticide compounds for human and environmental health is currently unclear. Most toxicity assessments are based on results from a single contaminant.

loess (Southern Iowa Drift Plains) than in streams draining till soils (Des Moines Lobe or the Iowan Surface). Because of differences in soil properties, triazine pesticide-use rates are apparently less in areas dominated by till soils such as the Des Moines Lobe and Iowan Surface landforms (Stoltenberg and Pope, 1990). The high pH of the till soils (increased calcium carbonate content) results in more triazine herbicides available for plants and greater persistence. Less triazine herbicides have been applied to till soils (particularly in the Des Moines Lobe) because the effects of triazine herbicides can “carry over” to soybeans planted after corn. Results from a regional low-flow synoptic study (Sorenson and others, 1999) indicate that the percentage of blue-green algae in stream periphyton communities increases with total (parent compounds plus degradates) triazine herbicide concentrations (Porter and others, 2001).

Runoff from rains soon after application washes large quantities of pesticides into streams. Concentrations of pesticides and their degradates were highest in the late spring and early summer when intense rains occurred soon after application (fig. 23). Pesticides and their degradates are transported from the Eastern Iowa Basins in largest quantities during the late spring and early summer. Pesticide degradates make up the largest part of the pesticide load transported to the Mississippi River. Pesticide data from the Iowa River at Wapello, Iowa, illustrate that the monthly degradate load was higher than the loads of the parent compounds throughout the year (fig. 25) but were particularly dominant during the spring and early summer and late fall and winter periods. Typically, the loads for all compounds were largest during the spring and early summer (March through June) when significant runoff events transported pesticide compounds to streams. In the fall

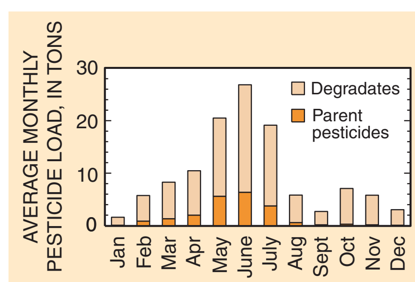


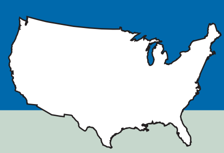
Figure 25. The most frequently used pesticides begin breaking down before being transported from the Study Unit to the Mississippi River. More than 80 percent of the yearly pesticide load in the Iowa River at Wapello is pesticide degradates. Of the yearly load, about 57 percent was transported from the Study Unit during May, June, and July.

and winter months, however, the pesticide degradates accounted for nearly all of the pesticide loads (fig. 25). Parent compounds accounted for only 3 percent (December) to 27 percent (May) of the total pesticide compounds transported from the Iowa River. Much of the water and dissolved pesticide compounds originated from ground-water inflow during the relatively dry late fall and winter months. The presence of relatively high concentrations of alachlor and metolachlor degradates in the fall and winter, several months after pesticide application when parent compounds have all but disappeared, indicates that these compounds are relatively stable.

Other Organic Compounds

The gasoline additive MTBE was the most commonly detected volatile organic compound in ground water. Shallow alluvial ground water in urban areas is susceptible to contamination from organic compounds resulting from activities such as transportation, manufacturing, and service industries. Volatile organic compounds (VOCs) were detected in 40 percent of alluvial samples from urban areas and 10 percent of the samples from agricultural areas. Methyl *tert*-butyl ether was the most frequently detected VOC and was present in 23 percent of samples from urban areas (fig. 26). Although most detected concentrations were low, MTBE concentrations from two urban monitoring wells were at levels of potential concern for human health (USEPA drinking-water advisory of 20 to 40 µg/L). MTBE was commonly found with other gasoline compounds (benzene, ethylbenzene, toluene, and xylene), indicating that contamination likely originated from leaking fuel storage tanks and possibly from surface spills. MTBE was not detected in agricultural areas. Solvents were detected in less than 15 percent of the samples, and other VOCs were detected in less than 10 percent of the samples.

Water from deeper in the alluvial aquifers and in the deeper Silurian-Devonian and Upper Carbonate



MTBE DETECTION RATES ARE SIMILAR TO THE AVERAGE DETECTION RATE IN THE NATION

Methyl *tert*-butyl ether (MTBE), a compound added to gasoline to enhance the octane content or to ensure cleaner burning with reduced carbon monoxide emissions, was detected in the alluvial aquifers underlying towns and cities in the Eastern Iowa Basins at a rate similar to the average detection rate in the United States (Squillace and others, 1999). However, detection rates (fig. 26) were not as great as in shallow, vulnerable aquifers in Denver, Colorado (Bruce and McMahon, 1996), and other areas where MTBE has been used extensively to reduce carbon monoxide emissions. MTBE also has been detected in areas where MTBE is used only to enhance the octane content (Zorgorski and others, 1997). Although ethanol is commonly added to gasoline in Iowa, MTBE has also been added to increase the octane level. Legislatively mandated sampling of soil and ground water from leaking underground storage tank (LUST) sites in Iowa verified that MTBE is prevalent in gasoline-contaminated areas (Iowa Department of Natural Resources, 2000b). MTBE was present in ground water at about 59 percent of the 523 LUST sites in 248 Iowa towns and cities.

The effects of MTBE on human health are not fully understood, but MTBE has been linked to headaches, nausea, dizziness, and breathing difficulties (Melnick and others, 1997). Experimental studies indicate that MTBE is carcinogenic in rats and mice (Melnick and others, 1997).

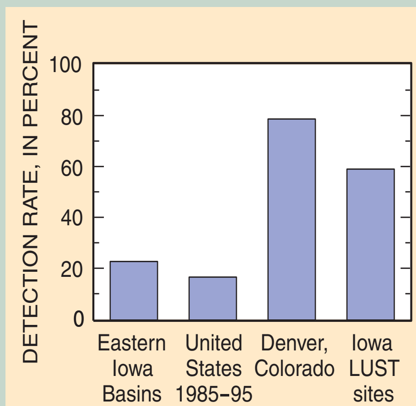


Figure 26. The presence of the gasoline additive MTBE in alluvial aquifers in urban areas reflects the common occurrence of MTBE at gasoline-contaminated sites in Iowa.

BIOLOGICAL COMMUNITIES IN STREAMS CONSIST OF ORGANISMS THAT ARE MODERATELY TO HIGHLY TOLERANT OF ENVIRONMENTAL DEGRADATION

Biological communities (algae, fish, and invertebrates) in streams in the Eastern Iowa Basins generally rank in the middle 50th to highest 25th percentile most tolerant of environmental degradation nationally (fig. 27). Commonly, biological communities in streams change in response to environmental changes (degradation). Degradation can result from a variety of factors that modify habitat or other environmental features such as land use, water chemistry, streamflow, and others. The biological community may change from few individuals of many species to a community of many individuals of a few tolerant species.

Algal status focuses on the changes in the percentage of certain algae in response to increasing siltation and seems to correlate relatively well with higher nutrient concentrations in many regions. Invertebrate status is the average of 11 invertebrate (primarily insects, worms, crayfish, and clams) metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. Fish status is the sum of scores of four fish metrics (percent tolerant, omnivorous, non-native individuals, and percent individuals with external anomalies) that change (increase) in association with water-quality degradation. For all indicators, higher values indicate a more degraded stream site.

Community differences occur among streams in the Eastern Iowa Basins, but these differences are small in relation to differences across the Nation. From a national perspective, algal status was moderate to high in all Study Unit streams and rivers and corresponds with high concentrations of dissolved and total nutrients. With one exception (Wapsipinicon River near DeWitt), invertebrate status tended to rank in the middle to lowest 25th percentile, indicating a moderate degree of degradation in relation to the rest of the Nation. Because of nutrient enrichment and subsequent abundance of algae and organic material, an abundant food supply is present to support a diverse invertebrate community. From a local and regional perspective, invertebrate status indicated greater degradation in large rivers than small streams. However, lower status in the Skunk River may be associated more with better habitat at that site than any quantitative differences in water chemistry among other large rivers. Fish communities tended to be ranked highest (most degraded) to moderate when compared nationally. Based on the presence of more species sensitive to environmental stress, the fish population at Wapsipinicon River near DeWitt was minimally affected by environmental degradation in relation to other sites nationally.

Landform/land-use setting	Stream or river (see p. 26)	Algal status	Invertebrate status	Fish status
Streams				
Reference site	Wapsipinicon River near Tripoli	Middle 50	Lowest 25	Middle 50
Des Moines Lobe	Iowa River near Rowan	Middle 50	Middle 50	Highest 25
Des Moines Lobe with concentrated AFOs	South Fork Iowa River near New Providence	Highest 25	Middle 50	Middle 50
Southern Iowa Drift Plain	Old Mans Creek near Iowa City	Highest 25	Middle 50	Highest 25
Iowan Karst	Flood Creek near Powersville	Highest 25	Middle 50	Highest 25
Iowan Surface	Wolf Creek near Dysart	Middle 50	Middle 50	Highest 25
Large Rivers				
Mixed	Wapsipinicon River near DeWitt	Middle 50	Highest 25	Lowest 25
Mixed	Iowa River at Marengo	Highest 25	Middle 50	Middle 50
Mixed	Cedar River near Conesville	Middle 50	Middle 50	Middle 50
Mixed	Iowa River at Wapello	Highest 25	Middle 50	Middle 50
Mixed	Skunk River at Augusta	Highest 25	Lowest 25	Highest 25

■ Highest 25 percent nationally

■ Middle 50 percent nationally

■ Lowest 25 percent nationally

National network represents 140 sites in the NAWQA national basic fixed-site network that have algal, invertebrate (primarily insects, worms, crayfish, clams), and fish data

Figure 27. Status of biological communities—comparison of Eastern Iowa Basins sites to selected national network sites.

bedrock aquifers used for rural domestic supply rarely contained detectable concentrations of VOCs, even though gasoline is commonly stored and solvents are at times used in the vicinity of these wells.

Pesticides banned or restricted in the 1970s and 1980s are still present in fish tissue. Although no longer in use, residue from organochlorine insecticides (chlordane, DDT, dieldrin, and heptachlor epoxide) is still found in fish-tissue samples collected from eastern Iowa streams (Roberts, 1997) but not at levels of concern for human health. Concentrations were relatively higher in agricultural than urban streams, and fish from the Wapsipinicon River Basin contained lower concentrations of contaminants than fish from the Cedar or Iowa River Basins. Although aldrin, an organochlorine pesticide, has been banned since the 1970s, its degradate, dieldrin, was present in five stream samples during or immediately following spring runoff. Dieldrin was present in tissue samples collected from carp at 15 of 16 sites in eastern Iowa, and concentrations in fish seem to be associated with agricultural settings (Roberts, 1997). Concentrations that peaked in sediment deposited in Coralville Reservoir during the 1993 flood indicate that dieldrin is still transported in rivers during high flow (Kalkhoff and Van Metre, 1997). In contrast to the apparent agricultural source of dieldrin, the occurrence and concentration of PCBs (polychlorinated biphenyls) in fish tissue indicate an urban source for this contaminant (Roberts, 1997).

Biological Communities and Stream Habitat

The quality of water entering from runoff and ground water inflow is an important factor that influences the community structure of fish, invertebrates, and algae that live in the rivers and streams of the Eastern Iowa Basins. Stream habitat, the physical conditions in and along streams and rivers, also influences the occurrence and distribution of aquatic organisms. Water-quality degradation and habitat alteration resulting from agricultural and urban activities can adversely affect aquatic communities.

In general, degradation results in the replacement of native species with those that are more tolerant of nutrient and organic enrichment. There also tends to be a reduction in numbers of sensitive species, increases in abundance and dominance of tolerant species, and decreases in the diversity and evenness of biological communities that are typically considered an indicator of environmental stress.

Biological metrics that contain measures of the composition, abundance, function, and tolerance of species to environmental stress are commonly used to evaluate aquatic communities in relation to water quality and habitat conditions.

Fish populations are related to stream size and water-quality conditions. During 1996–98, 67 fish species representing 15 families were collected in six streams and six rivers in the Eastern Iowa Basins (Sullivan, 2000). The species and trophic composition, as well as the abundance and condition of fish communities, varied between the smaller streams and large river sites in the Eastern Iowa Basins. Measures of fish-community status, tolerance, structure, and index of biotic integrity (IBI) indicated that fish communities also differed among land uses and landforms in the basin (fig. 28). Habitat and water-quality data indicate that differences in species composition between rivers and streams are probably due to more than just stream size. Although differences in stream size and associated habitat differences favor the occurrence of different species, relatively higher concentrations of suspended sediment and phosphorus in large rivers may contribute to habitat degradation and eutrophication that may explain the relatively lower IBI scores at large river sites (Sullivan, 2000).

The two highest IBI-rated river sites were the Wapsipinicon River near DeWitt and the Cedar River at Gilbertville, an integrator site for

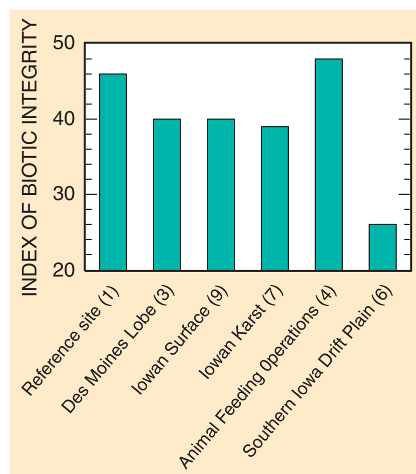


Figure 28. Healthy fish populations were present in one of the least affected (reference) and one of the most affected (animal feeding operations) streams in the study area. Factors other than water quality (stream habitat) also have an important effect on fish populations. (Site number in parentheses; see site map in “Study Unit Design” Section.)

the upper Cedar River watershed. River sites with the lowest IBI scores include the Skunk River at Augusta and three sites in the Iowa River Basin: Iowa River at Marengo, Old Mans Creek near Iowa City, and the most downstream integrator site (Iowa River at Wapello).

Agriculture and subsequent organic enrichment of the streams have likely reduced habitat, cover, and water-quality requirements for the maintenance of diverse fish populations and communities. However, the small number of fish species in Flood Creek (fig. 27) may be reflective of the karst hydrology in the basin; extended reaches of Flood Creek may be dry during low-flow conditions or periods of drought, limiting fish communities to juvenile fish or those with rapid recolonization rates.

Macroinvertebrate communities in the Eastern Iowa Basins reflect cumulative effects of both land use and downstream succession—the natural sequence of communities from headwater streams to large rivers (Vannote and others, 1980). More than 250 benthic invertebrate taxa were found in collections from submerged woody debris at 12 Basic Fixed Sites (see Glossary). Aquatic insects, including mayflies, net-spinning caddisflies, and midges, accounted for more than one-half of the organisms collected. The abundance of highly tolerant midges (Chironomidae) and worms (Oligochaeta), as well as collector-filterers was higher in large rivers, whereas the abundance of less-tolerant mayflies, stoneflies, and caddisflies (EPT taxa; see Glossary) was relatively larger in small tributary streams (Brigham and Sadorf, 2001). However, most invertebrate taxa in eastern Iowa streams and rivers are considered to be tolerant of nutrient and organic enrichment (Hilsenhoff, 1987). Stream velocity, rates of stream respiration, minimum dissolved oxygen, wooded-riparian zones, and the composition and abundance of periphyton were the primary factors associated with invertebrate community structure (M.A. Harris, U.S. Geological Survey, written commun., 2000).

In general, invertebrate diversity was lower in unshaded streams with silt, sand, or gravel bottoms (for example, Iowa River near Rowan and Old Mans Creek) than in shaded streams with bedrock or large rocks (for example, Flood Creek and Wapsipinicon River near Tripoli). Despite similarities in agricultural land-use intensity in the Midwestern Corn Belt, invertebrate communities reveal substantial differences in the quality of streams and rivers, corresponding to physical (modifications of stream channels and riparian zones) and hydrologic (rainfall-runoff and ground-water relations) differences among basins (M.A. Harris, U.S. Geological Survey, written commun., 2000).

Algal communities are dominated by nutrient- and sediment-tolerant taxa. More than 330 algal species were found in periphyton collections from submerged woody debris. Algal communities were dominated by taxa that are tolerant to nutrients and other agricultural contaminants such as herbicides and sediment.

Relative differences are seen in algal status (an indicator of nutrient and sediment enrichment) and biomass among sites from a regional and local perspective. For example, algal biomass (the amount of attached algae) was relatively higher in Old Mans Creek, Flood Creek, and the Cedar River at Gilbertville than other sites. Within the Eastern Iowa Basins, algal status was relatively better in the Wapsipinicon River near Tripoli (the reference site) and in the Cedar River near Gilbertville and Conesville.

During low-flow conditions in August 1997, shaded streams that drain permeable soils (for example, the upper Cedar and Wapsipinicon River Basins) were dominated by periphyton taxa (diatoms, red algae, and green algae) that are a good food source for invertebrates and fish. In contrast, channelized streams and rivers with poor riparian shading, impermeable soils, and slow velocity were dominated by phytoplankton taxa (notably blue-green algae) that are avoided as food sources and contribute to organic enrichment, higher rates of stream respiration, and lower dissolved oxygen concentrations during the night (Sorenson and others, 1999; Porter, 2000).

RIPARIAN BUFFER ZONES INFLUENCE THE QUALITY OF MIDWESTERN STREAMS AND RIVERS

Despite similar land use throughout the Corn Belt region of the Midwest, streams flowing through cropland differ considerably in their ecological characteristics, in part because of differences in riparian buffer zones (*see text box*). This conclusion is based on an investigation of 70 streams and rivers within three NAWQA Study Units in the upper Midwest during August 1997 (fig. 29; Sorenson and others, 1999; Porter and others, 2001). Specifically, increases in tree cover in buffer zones were associated with aquatic biological communities indicative of good stream quality, reduced nuisance algal growths, and maintenance of sufficient dissolved oxygen concentrations to support diverse communities of aquatic organisms. For example, the number of aquatic insects indicative of good stream quality tended to increase with increases in percentage of tree cover, especially in sites where streamflow and dissolved oxygen conditions were favorable. Fish communities, sampled at 24 sites in the UMIS Study Unit, also indicated better overall conditions in streams with wooded riparian zones than those with more open canopy (Stauffer and others, 2000).

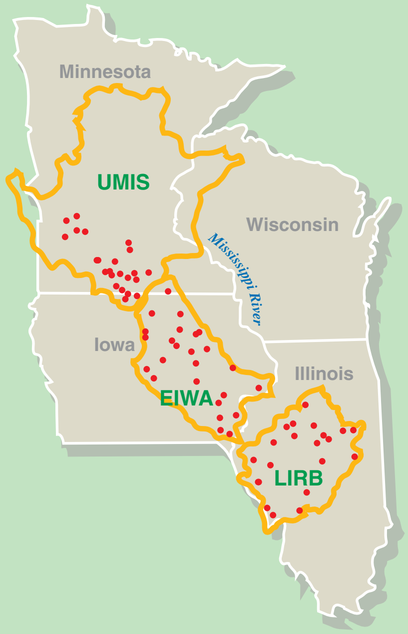


Figure 29. The influence of riparian buffer zones on the quality of 70 Midwestern streams and rivers was evaluated in the Upper Mississippi River (UMIS), Eastern Iowa (EIWA), and Lower Illinois River Basins (LIRB).

Streams with less tree cover, and thus less shading, contained relatively large growths of phytoplankton (algae suspended in the water) at levels considered indicative of eutrophication (Porter, 2000). Organic enrichment resulting from excessive algal production in some Midwestern streams may reduce dissolved oxygen concentrations and be detrimental to other requirements of aquatic organisms.

Shading from tree cover in riparian buffer zones may influence nutrient concentrations indirectly by reducing the growth of phytoplankton. In streams where phytoplankton were abundant (often where buffer zones were thin or lacking), dissolved nitrate concentrations were significantly lower (fig. 30; Porter, 2000). The lower nutrient concentrations may result from uptake by the abundant phytoplankton. Thus, assessments of eutrophication would benefit from consideration of biological communities and the riparian zone, rather than being based solely on nutrient concentrations in the water.

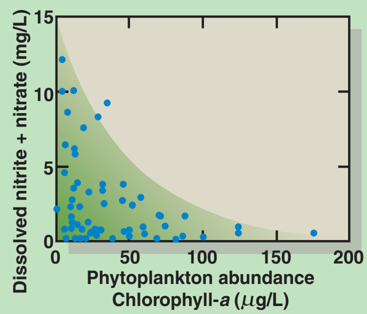


Figure 30. Dissolved nutrient concentrations decreased in eutrophic streams with excessive algal productivity. Rates of nutrient uptake by the algae can exceed rates at which nutrients are transported by streams during low-flow conditions.

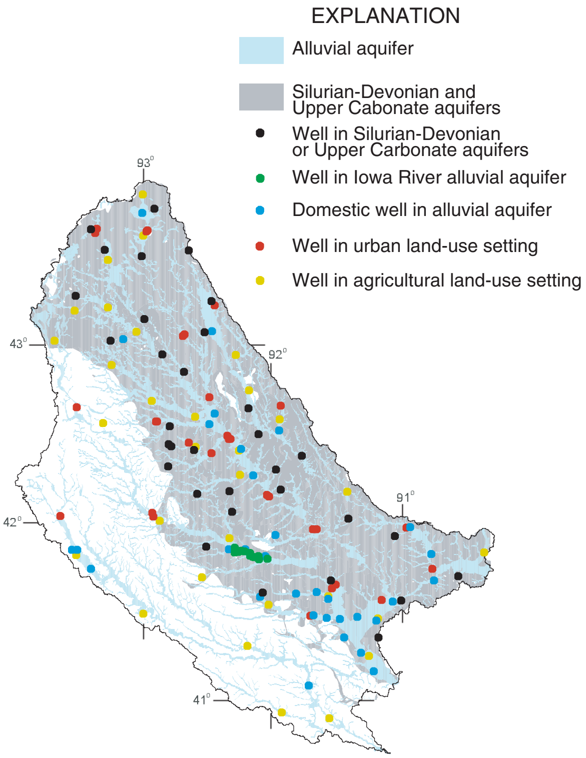
Digital images derived from USGS topographic maps were used to estimate the percentage of trees in a riparian buffer zone (a 100-meter width on each side of the stream) for 2- to 3-mile segments upstream from each sampling site, supplemented by vegetation surveys at the sampling site (Sorenson and others, 1999).

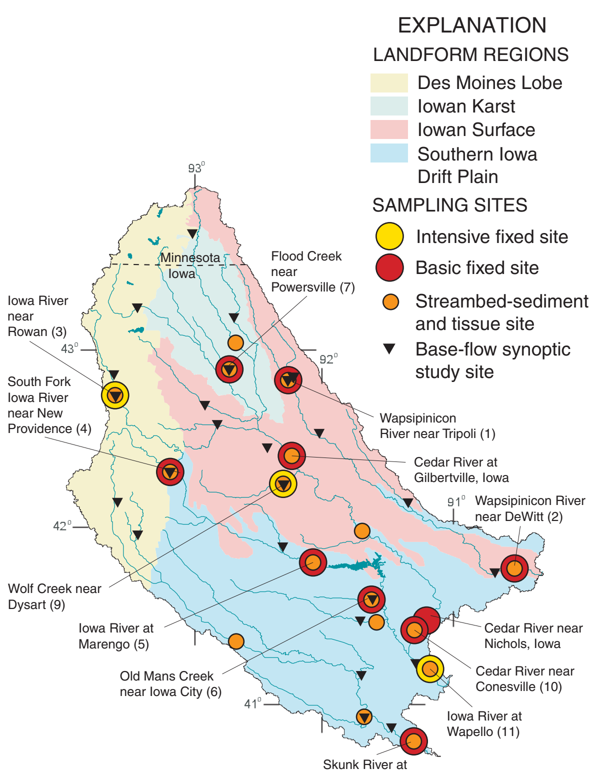
Resource agencies, including the U.S. Department of Agriculture, encourage maintenance of strips of trees or grass between cropland and streams as a best management practice. These "riparian buffer zones" are thought to intercept runoff of sediment and chemicals from fields, promote bank stability, and provide shading and habitat for aquatic life (Osborne and Kovacic, 1993). Riparian buffer zones should be considered along with other important factors that affect chemical and biological indicators of stream quality, such as soil drainage properties and stream hydrology (Porter and others, 2001).

The objective of the Eastern Iowa Basins NAWQA study was to assess the water-quality conditions in streams and ground water in the Study Unit. The study design is based on a nationally consistent structure that incorporates an interdisciplinary approach (Gilliom and others, 1995). Stream-water quality was assessed using three interrelated components: stream chemistry, streambed-sediment chemistry, and stream ecology. Ground-water quality of the alluvial aquifers was selected for assessment because these aquifers are the major source of water for municipal and domestic supplies and they provide flow to streams. Water quality in the Silurian-Devonian and Upper Carbonate aquifers also was investigated.

Stream Chemistry

The Basic Fixed Site sampling network was designed to characterize the effects of physiographic differences on water quality in the primarily agricultural Study Unit. Water-chemistry, bed-sediment, and reservoir-core data were collected. Sites were selected on large rivers and smaller streams. Fixed sites on large rivers were located near the mouth of the four major rivers to characterize the integrated effects of differing land use and environmental setting on stream quality. Two additional large river sites were chosen to assess the upper part of the Cedar River and the Iowa River, before it flows into Coralville Reservoir. Fixed sites on streams were selected to characterize each of the physiographic areas. A reference site was selected on a watershed that retains a large amount of bottomland wetlands. Another site was selected to assess the effects of concentrated animal feeding operations on stream quality. A subset of the Basic Fixed Site network was intensively sampled (weekly to biweekly) through the spring and summer of 1997. Two synoptic studies were conducted during base-flow conditions (high and low base flow) to improve the spatial resolution and to better evaluate the effects of soil type and riparian buffers on stream-water quality and biological communities.





Stream Ecology

Ecological data including fish-tissue chemistry and fish, macroinvertebrate, and algal community structure were collected to provide better understanding of the relations among physical, chemical, and biological characteristics of a stream. Data were collected at the Basic Fixed Site sampling network plus four additional sites to provide better spatial coverage.

Ground-Water Chemistry

The ground-water network was designed to characterize water quality in the most heavily used aquifers in the Study Unit. A Study Unit survey characterized the water quality in the Silurian-Devonian and Upper Carbonate bedrock aquifers, the second greatest source of municipal and domestic supplies in the Study Unit. Another Study Unit survey characterized the water quality of the alluvial aquifers using domestic wells. Land-use studies assessed the occurrence and distribution of water-quality constituents in recently recharged water in the alluvial aquifers. Agricultural and urban land-use effects on quality of shallow ground water was characterized by sampling two networks of monitoring wells constructed at randomly selected sites.

SUMMARY OF DATA COLLECTION IN THE EASTERN IOWA BASINS, 1996–98

Study component	What data were collected and why	Types of sites sampled	Number of sites	Sampling frequency and period
Stream chemistry				
Basic Fixed Sites—large rivers	Major ions, organic carbon, suspended sediment, nutrients, pesticides, and streamflow were determined to describe concentrations and the amount of selected constituents transported from the study area	Streams draining basins from about 2,300 to more than 12,000 square miles that integrate the effects of urban and agricultural land use and physiographic regions	6 in 1996, 5 in 1997–98	Monthly beginning in March 1996 and during selected flood events
Basic Fixed Sites—streams	Major ions, organic carbon, suspended sediment, nutrients, pesticides, and streamflow were determined to evaluate physiographic effects on stream-water quality	Streams draining basins from 120 to 418 square miles of homogeneous land use and physiography	6	Monthly beginning in March 1996 and during selected flood events
Intensive Fixed Sites	Major ions, organic carbon, suspended sediment, nutrients, pesticides, and streamflow were determined to define short-term temporal variability	One large river and two stream Basic Fixed Sites	3	Weekly during 1997 growing season; biweekly for remainder of the year
Base-flow synoptic study	Nutrients, pesticides, organic carbon, and streamflow were determined to refine spatial variability during both low and high base-flow conditions	Streams draining basins ranging from 120 to 530 square miles representing greater than 90 percent agricultural land use	25	August 1997 and May 1998
Bed-sediment chemistry				
Bed sediment and tissue	Trace elements, organochlorine, and semivolatile organic compounds in streambed sediment to determine presence of these potentially toxic, hydrophobic compounds	Ecological sites—Large river and tributary/headwater fixed sites plus four additional sites for better spatial coverage	16	September 1995
Reservoir core study	Trace elements and organochlorine compounds in sediment to determine the historical occurrence (from filling in 1958 to 1993)	Site in a deep depositional zone of the Coralville Reservoir about 1.5 miles upstream from the dam	1	November 1993
Stream ecology				
Bed sediment and tissue	Trace elements and organochlorine compounds in fish tissue to determine occurrence	Ecological sites	16	September 1995
Intensive assessments	Fish, benthic invertebrates, algae, and aquatic and riparian habitat were sampled and described to assess community structure and to document within stream and annual variation	Ecological sites	12	All fixed sites in 1996 and intensive sites in 1997–98
Ecological synoptic survey	Benthic invertebrates, algae, and aquatic and riparian habitat were sampled to assess biological responses in relation to water quality and hydrologic variability	Streams draining basins ranging from 120 to 530 square miles representing greater than 90 percent agricultural land use	25	August 1997
Ground-water chemistry				
Bedrock aquifer survey	Major ions, nutrients, pesticides, pesticide degradates, VOCs, and tritium were determined to assess quality in second most-used aquifer in Study Unit	Existing domestic wells completed in the Silurian-Devonian aquifer (32–700 feet deep)	33	June–July 1996
Alluvial aquifer survey	The same constituents as in bedrock aquifer survey were determined to assess quality in most-used aquifer in the Study Unit	Existing domestic wells completed in unconsolidated alluvial deposits	32	June–July 1998
Land-use effects study—agricultural and urban	The same constituents as in bedrock aquifer survey were determined to assess water-quality differences due to agricultural and urban land use	Newly constructed monitoring wells at sites randomly selected on alluvial deposits and completed at the water table (31 agricultural and 30 urban wells)	61	June–August 1997
Ground-water chemistry special study				
Changing land-use study	The same constituents as in bedrock aquifer survey were determined to assess changes in water-quality due to conversion of row crops to wetlands and prairie	Existing monitoring wells plus three new monitoring wells completed at various depths in the Iowa River alluvial aquifer	28	August 1996 and 1998

Acre-foot—A volume of water equal to 1 foot in depth and covering 1 acre; equivalent to 43,560 cubic feet or 325,851 gallons.

Algae—Chlorophyll-bearing nonvascular, primarily aquatic species that have no true roots, stems, or leaves; most algae are microscopic, but some species can be as large as vascular plants.

Alluvial aquifer—A water-bearing deposit of unconsolidated material (sand and gravel) left behind by a river or other flowing water.

Alluvium—A general term for clay, silt, sand, and gravel deposited by a river or stream in the bed of the stream or on its flood plain.

Ammonia—A compound of nitrogen and hydrogen (NH_3) that is a common by-product of animal waste. Ammonia readily converts to nitrate in soils and streams.

Aquatic guidelines—Specific levels of water quality which, if reached, may adversely affect aquatic life. These are nonenforceable guidelines issued by a governmental agency or other institution.

Aquifer—A water-bearing layer of soil, sand, gravel, or rock that will yield usable quantities of water to a well.

Base flow—Sustained, low flow in a stream; ground-water discharge is the source of base flow in most places.

Basic Fixed Sites—Sites on streams at which streamflow is measured and samples are collected for temperature, salinity, suspended sediment, major ions, nutrients, and organic carbon to assess the broad-scale spatial and temporal character and transport of inorganic constituents of streamwater in relation to hydrologic conditions and environmental settings.

Breakdown product—A compound derived by chemical, biological, or physical action upon a pesticide. The breakdown is a natural process which may result in a more toxic or a less toxic compound and a more or less persistent compound.

Concentration—The amount or mass of a substance present in a given volume or mass of sample. Usually expressed as micrograms per liter (water sample) or micrograms per kilogram (sediment or tissue sample).

Constituent—A chemical or biological substance in water, sediment, or biota that can be measured by an analytical method.

Contamination—Degradation of water quality compared to original or natural conditions due to human activity.

Cubic foot per second (ft^3/s, or cfs)—Rate of water discharge representing a volume of 1 cubic foot passing a given point during 1 second, equivalent to approximately 7.48 gallons per second or 448.8 gallons per minute or 0.02832 cubic meter per second.

Degradate—See Breakdown product.

Detection limit—The minimum concentration of a substance that can be identified, measured, and reported within 99 percent confidence that the analyte concentration is greater than zero; determined from analysis of a sample in a given matrix containing the analyte.

Discharge—Rate of fluid flow passing a given point at a given moment in time, expressed as volume per unit of time.

Drainage basin—The portion of the surface of the Earth that contributes water to a stream through overland run-off, including tributaries and impoundments.

Drinking-water standard or guideline—A threshold concentration in a public drinking-water supply, designed to protect human health. As defined here, standards are U.S. Environmental Protection Agency regulations that specify the maximum contamination levels for public water systems required to protect the public welfare; guidelines have no regulatory status and are issued in an advisory capacity.

Ecoregion—An area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables.

EPT richness index—An index based on the sum of the number of taxa in three insect orders, Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies), that are composed primarily of species considered to be relatively intolerant to environmental alterations.

Eutrophication—The process by which water becomes enriched with plant nutrients, most commonly phosphorus and nitrogen.

Ground water—In general, any water that exists beneath the land surface, but more commonly applied to water in fully saturated soils and geologic formations.

Habitat—The part of the physical environment where plants and animals live.

Hypoxia—Seasonally depleted dissolved oxygen concentrations (less than 2 milligrams per liter) in a water body

Index of Biotic Integrity (IBI)—An aggregated number, or index, based on several attributes or metrics of a fish community that provides an assessment of biological conditions.

Indicator sites—Stream sampling sites located at outlets of drainage basins with relatively homogeneous land use and physiographic conditions; most indicator-site basins have drainage areas ranging from 100 to about 400 square miles.

Integrator or Mixed-use site—Stream sampling site located at an outlet of a drainage basin that contains multiple environmental settings. Most integrator sites are on major streams with relatively large drainage areas.

Intolerant organisms—Organisms that are not adaptable to human alterations to the environment and thus decline in numbers where human alterations occur. See also Tolerant species.

Karst—A type of topography that results from dissolution and collapse of carbonate rocks such as limestone and dolomite, and characterized by closed depressions or sinkholes, caves, and underground drainage.

Leaching—Refers to movement of pesticides or nutrients from land surface to ground water.

Load—General term that refers to a material or constituent in solution, in suspension, or in transport; usually expressed in terms of mass or volume.

Loess—Homogeneous, fine-grained sediment made up primarily of silt and clay, and deposited over a wide area (probably by wind).

Maximum contaminant level (MCL)—Maximum permissible level of a contaminant in water that is delivered to any user of a public water system. MCLs are enforceable standards established by the U.S. Environmental Protection Agency.

Median—The middle or central value in a distribution of data ranked in order of magnitude. The median is also known as the 50th percentile.

Monitoring well—A well designed for measuring water levels and testing ground-water quality.

Mouth—The place where a stream discharges to a larger stream, a lake, or the sea.

Nutrient—Element or compound essential for animal and plant growth. Common nutrients in fertilizer include nitrogen, phosphorus, and potassium.

Overland flow—The part of surface runoff flowing over land surfaces toward stream channels.

Periphyton—Organisms that grow on underwater surfaces; periphyton include algae, bacteria, fungi, protozoa, and other organisms.

Pesticide—A chemical applied to crops, rights-of-way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other "pests."

Physiography—A description of the surface features of the Earth, with an emphasis on the origin of landforms.

Plankton—Floating or weakly swimming organisms at the mercy of the waves and currents. Animals of the group are called zooplankton and the plants are called phytoplankton.

Radon—A naturally occurring, colorless, odorless, radioactive gas formed by the disintegration of the element radium; damaging to human lungs when inhaled.

Recharge—Water that infiltrates the ground and reaches the saturated zone.

Reference site—A NAWQA sampling site selected for its relatively undisturbed conditions.

Riparian zone—Pertaining to or located on the bank of a body of water, especially a stream.

Runoff—Excess rainwater or snowmelt that is transported to streams by overland flow, tile drains, or ground water.

Species diversity—An ecological concept that incorporates both the number of species in a particular sampling area and the evenness with which individuals are distributed among the various species.

Species (taxa) richness—The number of species (taxa) present in a defined area or sampling unit.

Study Unit—A major hydrologic system of the United States in which NAWQA studies are focused. Study Units are geographically defined by a combination of ground- and surface-water features and generally encompass more than 4,000 square miles of land area.

Tile drain—A buried perforated pipe designed to remove excess water from soils.

Tolerant species—Those species that are adaptable to (tolerant of) human alterations to the environment and often increase in number when human alterations occur.

Total concentration— Refers to the concentration of a constituent regardless of its form (dissolved or bound) in a sample.

Triazine herbicide—A class of herbicides containing a symmetrical triazine ring (a nitrogen-heterocyclic ring composed of three nitrogens and three carbons in an alternating sequence). Examples include atrazine, propazine, and simazine.

Tritium—A radioactive form of hydrogen with atoms of three times the mass of ordinary hydrogen; can be used to determine the age of water.

Unconsolidated deposit—Deposit of loosely bound sediment that typically fills topographically low areas.

Urban site—A site that has greater than 50 percent urbanized and less than 25 percent agricultural area.

Volatile organic compounds (VOCs)—Organic chemicals that have a high vapor pressure relative to their water solubility. VOCs include components of gasoline, fuel oils, and lubricants, as well as organic solvents, fumigants, some inert ingredients in pesticides, and some by-products of chlorine disinfection.

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APPENDIX—WATER-QUALITY DATA FROM THE EASTERN IOWA BASINS IN A NATIONAL CONTEXT

For a complete view of Eastern Iowa Basins data and for additional information about specific benchmarks used, visit our Web site at http://water.usgs.gov/nawqa/. Also visit the NAWQA Data Warehouse for access to NAWQA data sets at http://infotrek.er.usgs.gov/wdbctx/nawqa/nawqa.home.

This appendix is a summary of chemical concentrations and biological indicators assessed in the Eastern Iowa Basins. Selected results for this Study Unit are graphically compared to results from as many as 36 NAWQA Study Units investigated from 1991 to 1998 and to national water-quality benchmarks for human health, aquatic life, or fish-eating wildlife. The chemical and biological indicators shown were selected on the basis of frequent detection, detection at concentrations above a national benchmark, or regulatory or scientific importance. The graphs illustrate how conditions associated with each land use sampled in the Eastern Iowa Basins compare to results from across the Nation, and how conditions compare among the several land uses. Graphs for chemicals show only detected concentrations and, thus, care must be taken to evaluate detection frequencies in addition to concentrations when comparing study-unit and national results. For example, acetochlor concentrations in Eastern Iowa Basins agricultural streams were similar to the national distribution, but the detection frequency was much higher (79 percent compared to 33 percent).

CHEMICALS IN WATER

Concentrations and detection frequencies, Eastern Iowa Basins, 1996–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals

◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

- - Not measured or sample size less than two

12 Study-unit sample size. For ground water, the number of samples is equal to the number of wells sampled

National ranges of detected concentrations, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

Streams in agricultural areas
Streams in urban areas
Streams and rivers draining mixed land uses
Shallow ground water in agricultural areas
Shallow ground water in urban areas
Major aquifers

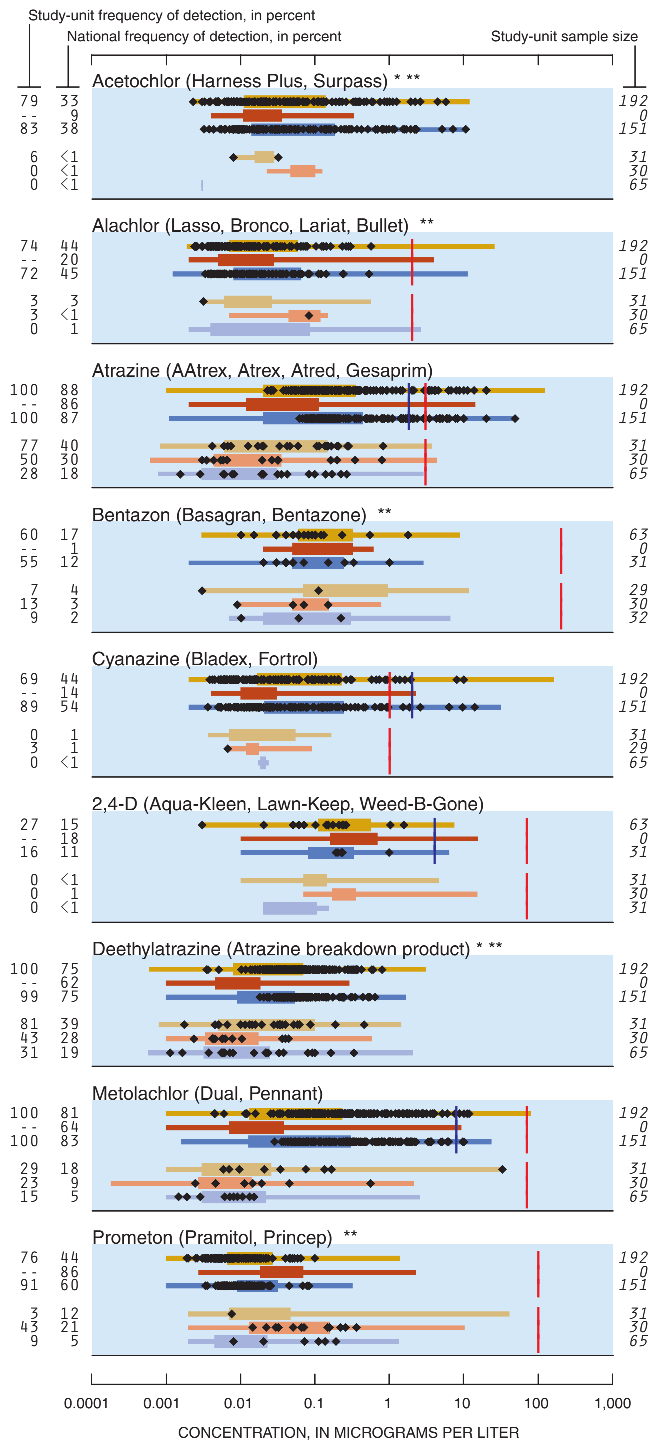
Lowest 25 percent | Middle 50 percent | Highest 25 percent

National water-quality benchmarks

National benchmarks include standards and guidelines related to drinking-water quality, criteria for protecting the health of aquatic life, and a goal for preventing stream eutrophication due to phosphorus. Sources include the U.S. Environmental Protection Agency and the Canadian Council of Ministers of the Environment

| Drinking-water quality (applies to ground water and surface water)
| Protection of aquatic life (applies to surface water only)
| Prevention of eutrophication in streams not flowing directly into lakes or impoundments
* No benchmark for drinking-water quality
** No benchmark for protection of aquatic life

Pesticides in water—Herbicides

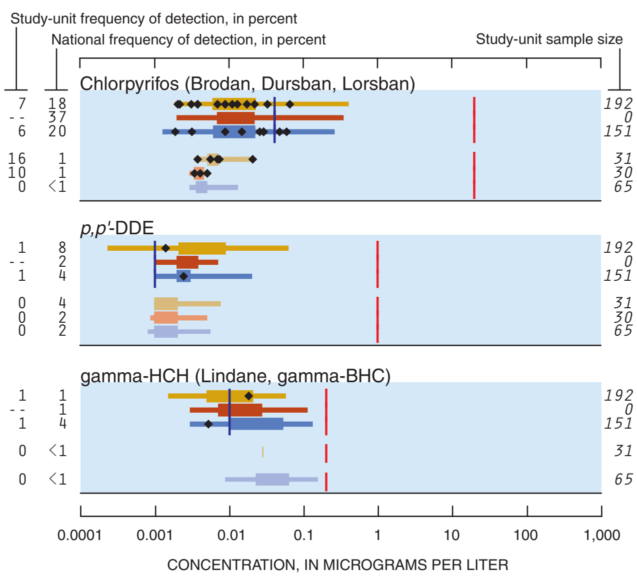


Other herbicides detected
Acifluorfen (Blazer, Tackle 2S) **
Bromacil (Hyvar X, Urox B, Bromax)
Bromoxynil (Buctril, Brominal) *
Butylate (Sutan +, Genate Plus, Butilate) **
DCPA (Dacthal, chlorthal-dimethyl) * **
Dicamba (Banvel, Dianat, Scotts Proturf)

Dichlorprop (2,4-DP, Seritox 50, Lentemul) * **
2,6-Diethylaniline (Alachlor breakdown product) * **
Diuron (Crisuron, Karmex, Diurex) **
EPTC (Eptam, Farmarox, Alirox) * **
Metribuzin (Lexone, Sencor)
Molinate (Ordram) * **
Napropamide (Devrinol) * **
Pendimethalin (Pre-M, Prowl, Stomp) * **
Picloram (Grazon, Tordon)
Pronamide (Kerb, Propyzamid) **
Propachlor (Ramrod, Satecid) **
Simazine (Princep, Caliber 90)
Tebuthiuron (Spike, Tebusan)
Triclopyr (Garlon, Grandstand, Redeem, Remedy) * **
Trifluralin (Treflan, Gowan, Tri-4, Trific)

Herbicides not detected
Benfluralin (Balan, Benefin, Bonalan) * **
Chloramben (Amiben, Amilon-WP, Vegiben) **
Clopyralid (Stinger, Lontrel, Transline) * **
2,4-DB (Butyrac, Butoxone, Embutox Plus, Embutone) * **
Dacthal mono-acid (Dacthal breakdown product) * **
Dinoseb (Dinosebe)
Ethalfluralin (Sonalan, Curbit) * **
Fenuron (Fenulon, Fenidim) * **
Fluometuron (Flo-Met, Cotoran) **
Linuron (Lorox, Linex, Sarclex, Linurex, Afalon) *
MCPA (Rhomene, Rhonox, Chiptox)
MCPB (Thistrol) * **
Neburon (Neburea, Neburyl, Noruben) * **
Norflurazon (Evital, Predict, Solicam, Zorial) * **
Oryzalin (Surflan, Dirimal) * **
Pebulate (Tillam, PEBC) * **
Propanil (Stam, Stampede, Wham) * **
Propham (Tuberite) **
2,4,5-T **
2,4,5-TP (Silvex, Fenoprop) **
Terbacil (Sinbar) **
Thiobencarb (Bolero, Saturn, Benthiocarb) * **
Triallate (Far-Go, Avadex BW, Tri-allate) *

Pesticides in water—Insecticides

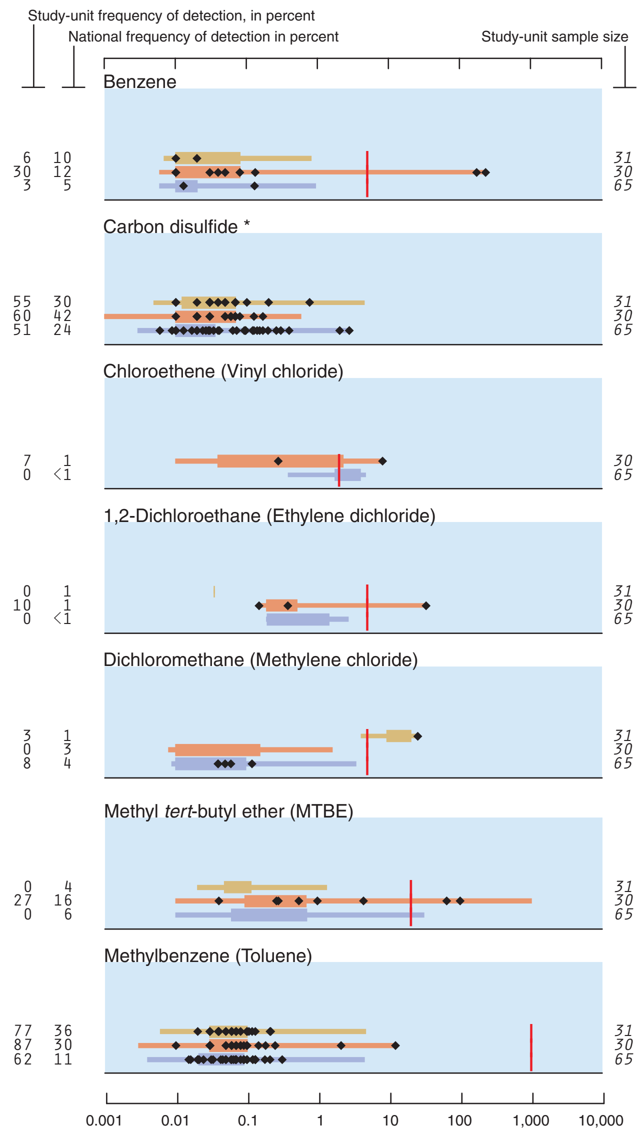


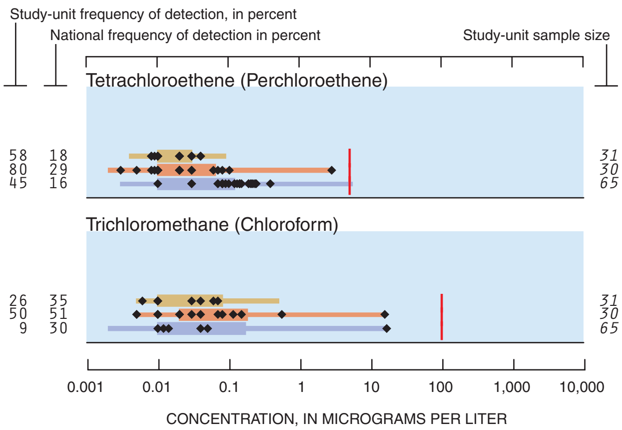
Other insecticides detected
Carbaryl (Carbamine, Denapon, Sevin)
Carbofuran (Furadan, Curaterr, Yaltox)
Diazinon (Basudin, Diazatol, Neocidol, Knox Out)
Dieldrin (Panoram D-31, Octalox, Compound 497)
Fonofos (Dyfonate, Capfos, Cudgel, Tycap) **
3-Hydroxycarbofuran (Carbofuran breakdown product) * **
Malathion (Malathion)

Insecticides not detected
Aldicarb (Temik, Ambush, Pounce)
Aldicarb sulfone (Standak, aldoxycarb)
Aldicarb sulfoxide (Aldicarb breakdown product)
Azinphos-methyl (Guthion, Gusathion M) *
Disulfoton (Disyston, Di-Syston) **
Ethoprop (Mocap, Ethoprophos) * **
alpha-HCH (alpha-BHC, alpha-lindane) **
Methiocarb (Slug-Geta, Grandslam, Mesurol) * **
Methomyl (Lanox, Lannate, Acinate) **
Methyl parathion (Penncap-M, Folidol-M) **
Oxamyl (Vydate L, Pratt) **
Parathion (Roethyl-P, Alkron, Panthion, Phoskil) *
cis-Permethrin (Ambush, Astro, Pounce) * **
Phorate (Thimet, Granutox, Geomet, Rampart) * **
Propargite (Comite, Omite, Ornamite) * **
Propoxur (Baygon, Blattanex, Unden, Proprotox) * **
Terbufos (Contraven, Counter, Pilarfox) **

Volatile organic compounds (VOCs) in ground water

These graphs represent data from 16 Study Units, sampled from 1996 to 1998

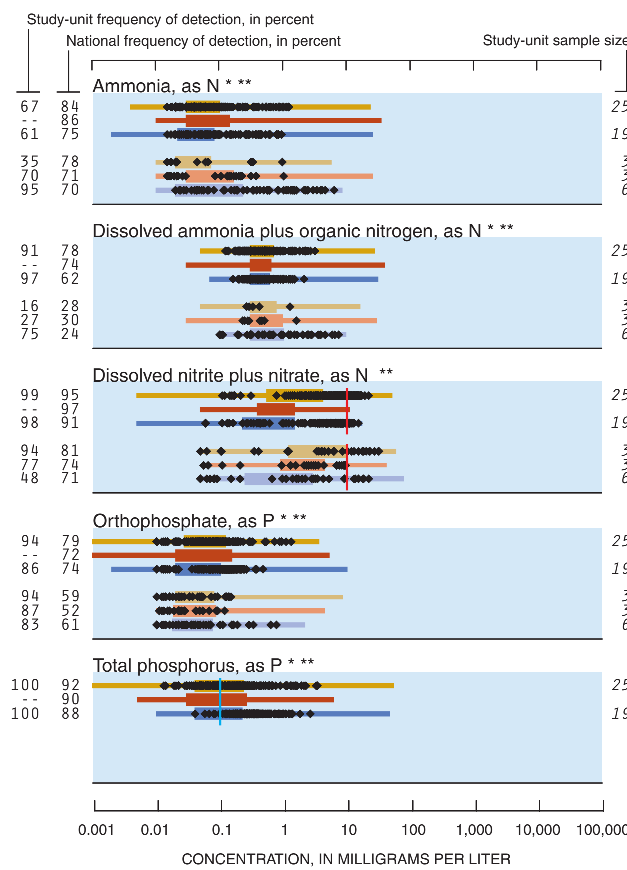




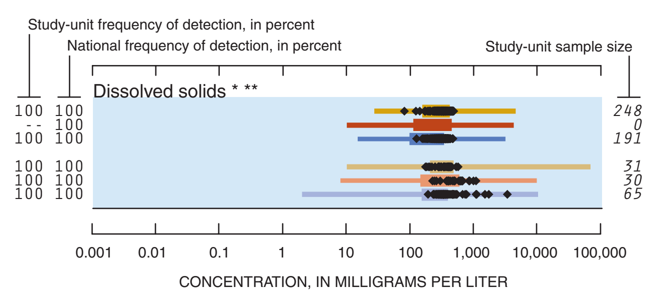
Other VOCs detected
tert-Amylmethylether (*tert*-amyl methyl ether (TAME)) *
Bromodichloromethane (Dichlorobromomethane)
Bromomethane (Methyl bromide)
2-Butanone (Methyl ethyl ketone (MEK)) *
n-Butylbenzene (1-Phenylbutane) *
sec-Butylbenzene *
tert-Butylbenzene *
Chlorobenzene (Monochlorobenzene)
Chlorodibromomethane (Dibromochloromethane)
Chloroethane (Ethyl chloride) *
Chloromethane (Methyl chloride)
1,3-Dichlorobenzene (*m*-Dichlorobenzene)
1,4-Dichlorobenzene (*p*-Dichlorobenzene)
Dichlorodifluoromethane (CFC 12, Freon 12)
1,1-Dichloroethane (Ethylidene dichloride) *
1,1-Dichloroethene (Vinylidene chloride)
trans-1,2-Dichloroethene ((E)-1,2-Dichlorothene)
cis-1,2-Dichloroethene ((Z)-1,2-Dichloroethene)
1,2-Dichloropropane (Propylene dichloride)
Diethyl ether (Ethyl ether) *
Diisopropyl ether (Diisopropylether (DIPE)) *
1,2-Dimethylbenzene (*o*-Xylene)
1,3 & 1,4-Dimethylbenzene (*m*-&*p*-Xylene)
1-4-Epoxy butane (Tetrahydrofuran, Diethylene oxide) *
Ethyl *tert*-butyl ether (Ethyl-*t*-butyl ether (ETBE)) *
1-Ethyl-2-methylbenzene (2-Ethyltoluene) *
Ethylbenzene (Phenylethane)
Iodomethane (Methyl iodide) *
Isopropylbenzene (Cumene) *
p-Isopropyltoluene (*p*-Cymene) *
Naphthalene
2-Propanone (Acetone) *
n-Propylbenzene (Isocumene) *
1,2,3,5-Tetramethylbenzene (Isodurene) *
Tribromomethane (Bromoform)
1,2,3-Trichlorobenzene *
1,1,1-Trichloroethane (Methylchloroform)
Trichloroethene (TCE)
1,2,3-Trichloropropane (Allyl trichloride)
1,2,3-Trimethylbenzene (Hemimellitene) *
1,2,4-Trimethylbenzene (Pseudocumene) *
1,3,5-Trimethylbenzene (Mesitylene) *

VOCs not detected
Bromobenzene (Phenyl bromide) *
Bromochloromethane (Methylene chlorobromide)
Bromoethene (Vinyl bromide) *
3-Chloro-1-propene (3-Chloropropene) *
1-Chloro-2-methylbenzene (*o*-Chlorotoluene)
1-Chloro-4-methylbenzene (*p*-Chlorotoluene)
1,2-Dibromo-3-chloropropane (DBCP, Nemagon)
1,2-Dibromoethane (Ethylene dibromide, EDB)
Dibromomethane (Methylene dibromide) *
trans-1,4-Dichloro-2-butene ((Z)-1,4-Dichloro-2-butene) *
1,2-Dichlorobenzene (*o*-Dichlorobenzene)
2,2-Dichloropropane *
1,3-Dichloropropane (Trimethylene dichloride) *
trans-1,3-Dichloropropene ((E)-1,3-Dichloropropene)
cis-1,3-Dichloropropene ((Z)-1,3-Dichloropropene)
1,1-Dichloropropene *
Ethenylbenzene (Styrene)
Ethyl methacrylate *
Hexachlorobutadiene
1,1,1,2,2,2-Hexachloroethane (Hexachloroethane)
2-Hexanone (Methyl butyl ketone (MBK)) *
Methyl acrylonitrile *
Methyl-2-methacrylate (Methyl methacrylate) *
4-Methyl-2-pentanone (Methyl isobutyl ketone (MIBK)) *
Methyl-2-propenoate (Methyl acrylate) *
2-Propenenitrile (Acrylonitrile)
1,1,2,2-Tetrachloroethane *
1,1,1,2-Tetrachloroethane
Tetrachloromethane (Carbon tetrachloride)
1,2,3,4-Tetramethylbenzene (Prehnitene) *
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon 113) *
1,2,4-Trichlorobenzene
1,1,2-Trichloroethane (Vinyl trichloride)
Trichlorofluoromethane (CFC 11, Freon 11)

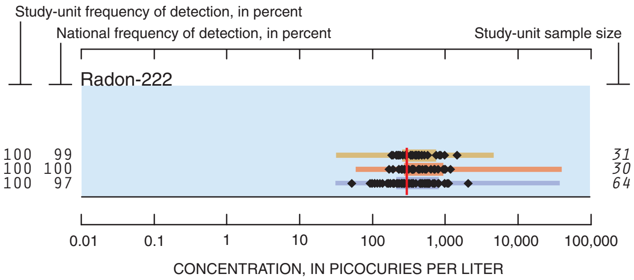
Nutrients in water



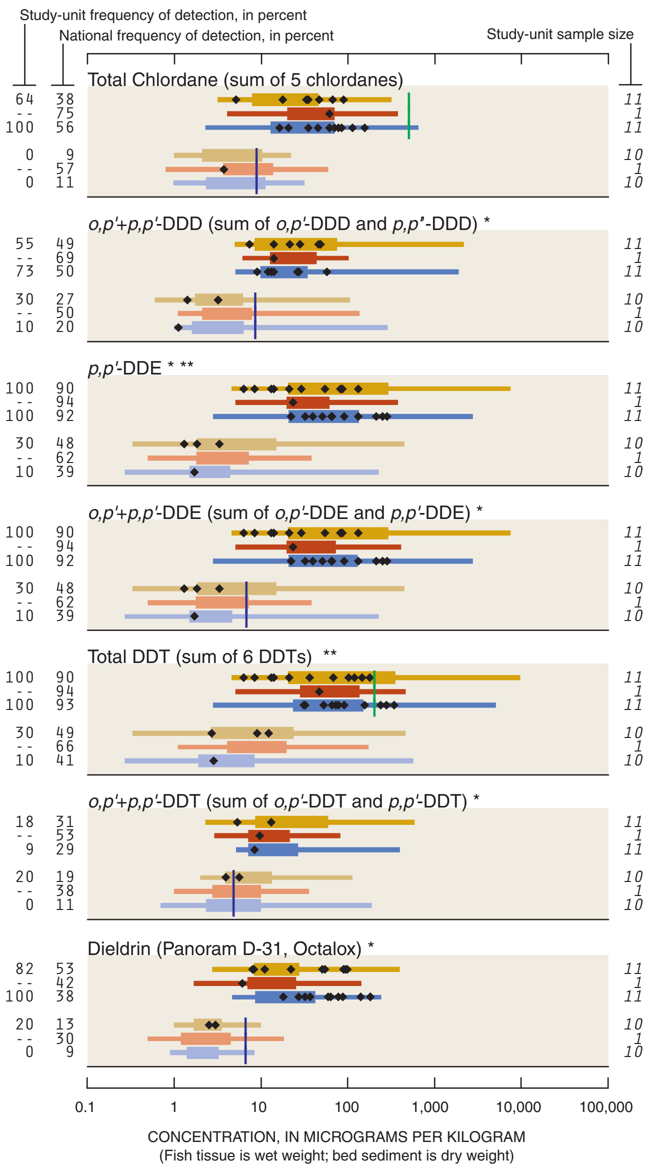
Dissolved solids in water



Trace elements in ground water



Organochlorines in fish tissue (whole body) and bed sediment



CHEMICALS IN FISH TISSUE AND BED SEDIMENT

Concentrations and detection frequencies, Eastern Iowa Basins, 1996–98—Detection sensitivity varies among chemicals and, thus, frequencies are not directly comparable among chemicals. Study-unit frequencies of detection are based on small sample sizes; the applicable sample size is specified in each graph

◆ Detected concentration in Study Unit

66 38 Frequencies of detection, in percent. Detection frequencies were not censored at any common reporting limit. The left-hand column is the study-unit frequency and the right-hand column is the national frequency

-- Not measured or sample size less than two

12 Study-unit sample size

National ranges of concentrations detected, by land use, in 36 NAWQA Study Units, 1991–98—Ranges include only samples in which a chemical was detected

Fish tissue from streams in agricultural areas
Fish tissue from streams in urban areas
Fish tissue from streams draining mixed land uses
Sediment from streams in agricultural areas
Sediment from streams in urban areas
Sediment from streams draining mixed land uses

Lowest 25 percent | Middle 50 percent | Highest 25 percent

National benchmarks for fish tissue and bed sediment

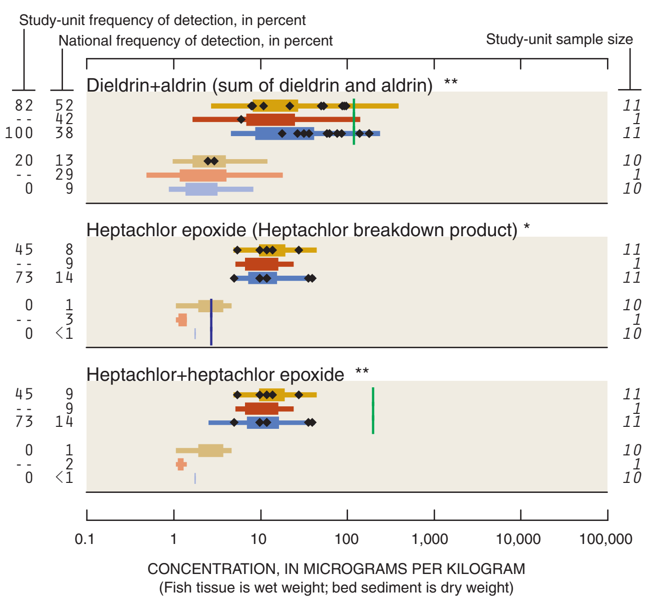
National benchmarks include standards and guidelines related to criteria for protection of the health of fish-eating wildlife and aquatic organisms. Sources include the U.S. Environmental Protection Agency, other Federal and State agencies, and the Canadian Council of Ministers of the Environment

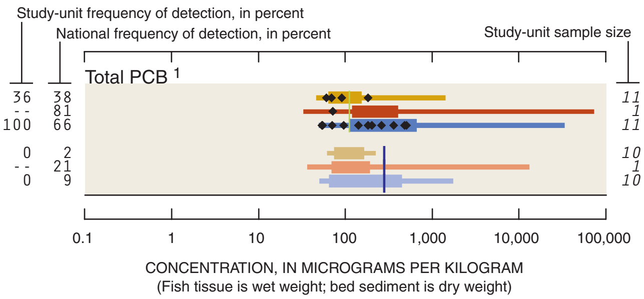
| Protection of fish-eating wildlife (applies to fish tissue)

| Protection of aquatic life (applies to bed sediment)

* No benchmark for protection of fish-eating wildlife

** No benchmark for protection of aquatic life



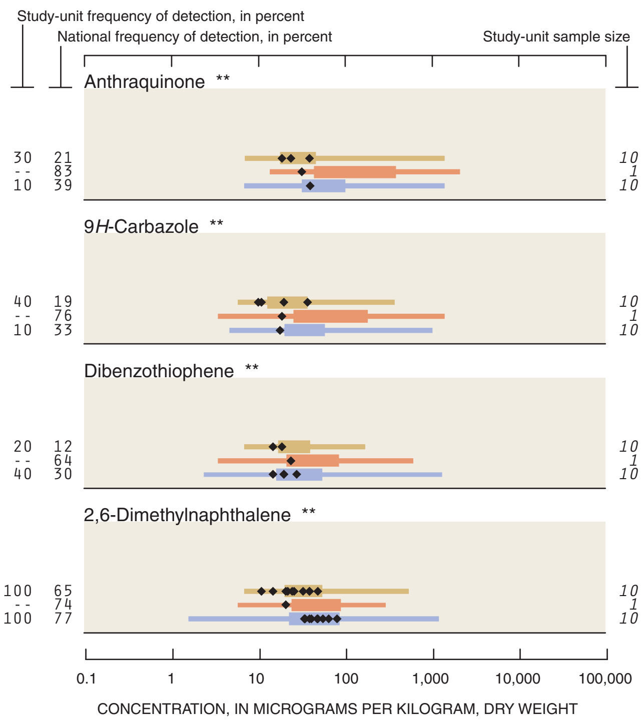


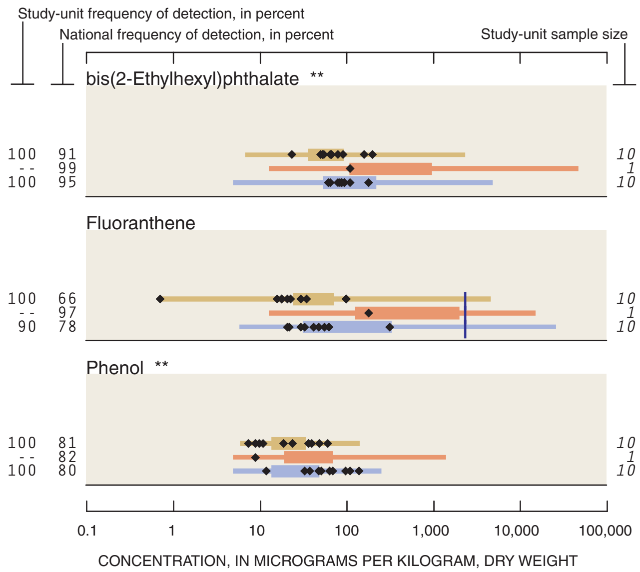
[1] The national detection frequencies for total PCB in sediment are biased low because about 30 percent of samples nationally had elevated detection levels compared to this Study Unit. See http://water.usgs.gov/nawqa/ for additional information.

Other organochlorines detected
DCPA (Dacthal, chlorthal-dimethyl) * **
Total-HCH (sum of alpha-HCH, beta-HCH, gamma-HCH, and delta-HCH) **
Mirex (Dechlorane) **
Pentachloroanisole (PCA) * **

Organochlorines not detected
Chloroneb (Chloronebe, Demosan) * **
Endosulfan I (alpha-Endosulfan, Thiodan) * **
Endrin (Endrine)
gamma-HCH (Lindane, gamma-BHC, Gammexane) *
Hexachlorobenzene (HCB) **
Isodrin (Isodrine, Compound 711) * **
p,p'-Methoxychlor (Marlate, methoxychlore) * **
o,p'-Methoxychlor * **
cis-Permethrin (Ambush, Astro, Pounce) * **
trans-Permethrin (Ambush, Astro, Pounce) * **
Toxaphene (Camphechlor, Hercules 3956) * **

Semivolatile organic compounds (SVOCs) in bed sediment



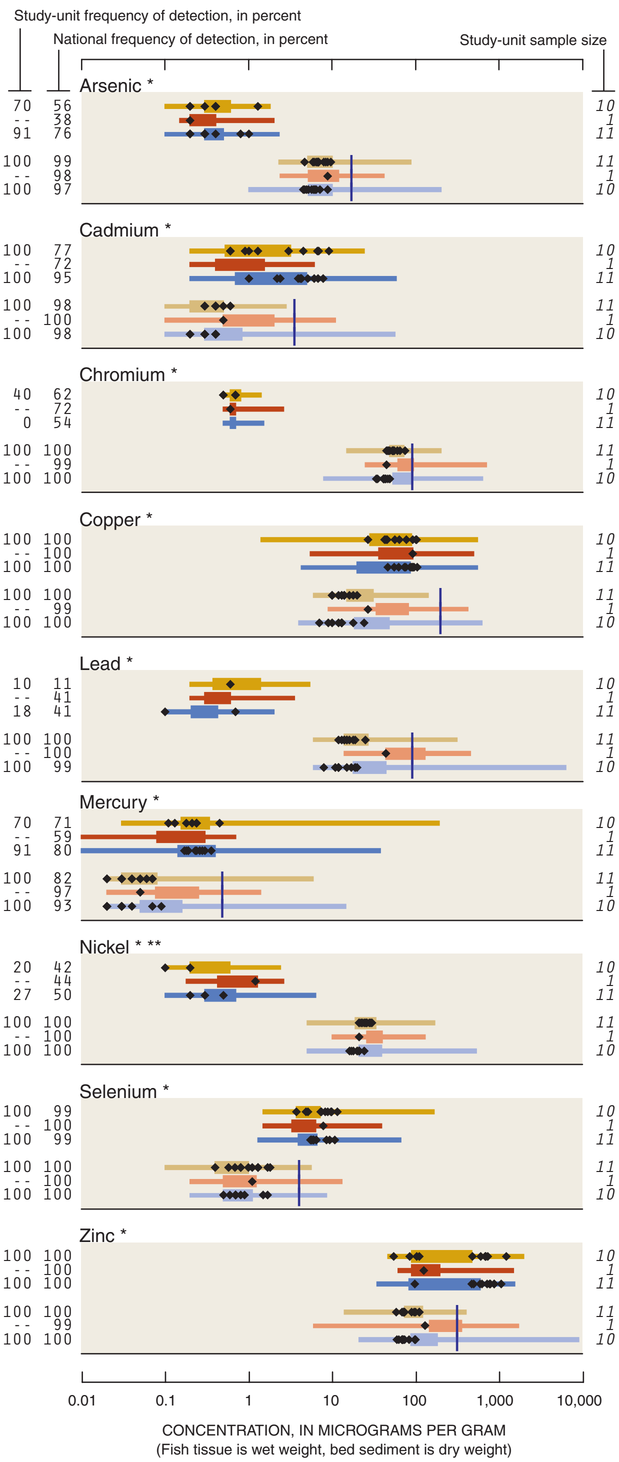


Other SVOCs detected
Acenaphthene
Acenaphthylene
Acridine **
Anthracene
Benz[*a*]anthracene
Benzo[*a*]pyrene
Benzo[*b*]fluoranthene **
Benzo[*ghi*]perylene **
Benzo[*k*]fluoranthene **
Butylbenzylphthalate **
Chrysene
p-Cresol **
Di-*n*-butylphthalate **
Di-*n*-octylphthalate **
Dibenz[*a,h*]anthracene
Diethylphthalate **
1,2-Dimethylnaphthalene **
1,6-Dimethylnaphthalene **
Dimethylphthalate **
2-Ethylnaphthalene **
9*H*-Fluorene (Fluorene)
Indeno[1,2,3-*cd*]pyrene **
Isoquinoline **
1-Methyl-9*H*-fluorene **
2-Methylanthracene **
4,5-Methylenephenanthrene **
1-Methylphenanthrene **
1-Methylpyrene **
Naphthalene
Phenanthrene
Pyrene
2,3,6-Trimethylnaphthalene **

SVOCs not detected
C8-Alkylphenol **
Azobenzene **
Benzo[*c*]cinnoline **
2,2-Biquinoline **
4-Bromophenyl-phenylether **
4-Chloro-3-methylphenol **
bis(2-Chloroethoxy)methane **
2-Chloronaphthalene **
2-Chlorophenol **
4-Chlorophenyl-phenylether **
1,2-Dichlorobenzene (*o*-Dichlorobenzene) **
1,3-Dichlorobenzene (*m*-Dichlorobenzene) **
1,4-Dichlorobenzene (*p*-Dichlorobenzene) **
3,5-Dimethylphenol **
2,4-Dinitrotoluene **
Isophorone **
Nitrobenzene **

N-Nitrosodi-*n*-propylamine **
N-Nitrosodiphenylamine **
Pentachloronitrobenzene **
Phenanthridine **
Quinoline **
1,2,4-Trichlorobenzene **

Trace elements in fish tissue (livers) and bed sediment



BIOLOGICAL INDICATORS

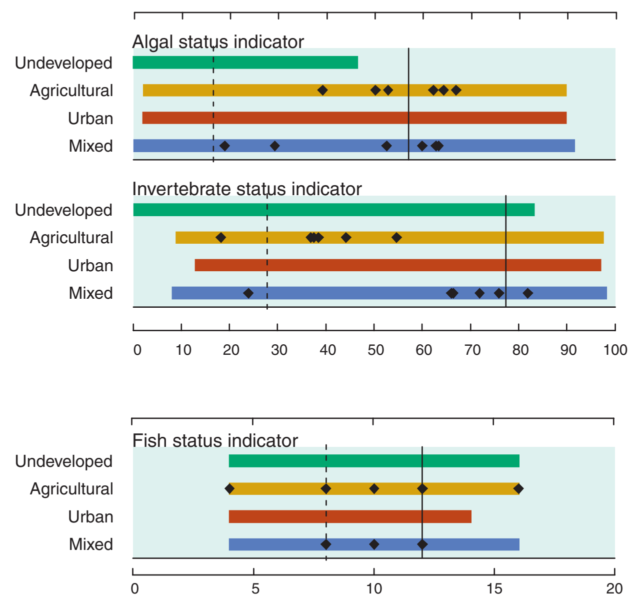
Higher national scores suggest habitat disturbance, water-quality degradation, or naturally harsh conditions. The status of algae, invertebrates (insects, worms, and clams), and fish provide a record of water-quality and stream conditions that water-chemistry indicators may not reveal. **Algal status** focuses on the changes in the percentage of certain algae in response to increasing siltation, and it often correlates with higher nutrient concentrations in some regions. **Invertebrate status** averages 11 metrics that summarize changes in richness, tolerance, trophic conditions, and dominance associated with water-quality degradation. **Fish status** sums the scores of four fish metrics (percent tolerant, omnivorous, non-native individuals, and percent individuals with external anomalies) that increase in association with water-quality degradation

Biological indicator value, Eastern Iowa Basins, by land use, 1996–98

◆ Biological status assessed at a site

National ranges of biological indicators, in 16 NAWQA Study Units, 1994–98

- Streams in undeveloped areas
- Streams in agricultural areas
- Streams in urban areas
- Streams in mixed-land-use areas
- 75th percentile
- 25th percentile



A COORDINATED EFFORT

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    Agricultural Research Service
U.S. Environmental Protection Agency, Region VII
U.S. Fish and Wildlife Service
U.S. Geological Survey
    Biological Resources Division
Iowa Department of Agriculture and Land Stewardship
    Pesticide Bureau
Iowa Department of Natural Resources
    Environmental Protection Division
    Geological Survey Bureau
    Fisheries Bureau
Minnesota Department of Natural Resources
    Minnesota Pollution Control Agency
    Minnesota Geological Survey
Linn County Iowa REAP
Linn County Iowa Conservation Board
Johnson County Iowa Board of Supervisors
Cedar Rapids Water Department
Iowa City Public Works
Iowa State University
    Center for Sustainable Agriculture
    Department of Botany
    Extension Service
University of Iowa
    Hygienics Laboratory
        Limnology Section
        Environmental Research
    Institute of Hydraulic Research
    Center for Health Effects on the Environment
University of Northern Iowa
    College of Natural Sciences
Wartburg College
    Biology Department
Iowa Farm Bureau Federation
Iowa Environmental Council
Iowa Ground Water Association
Izaak Walton League
Sierra Club
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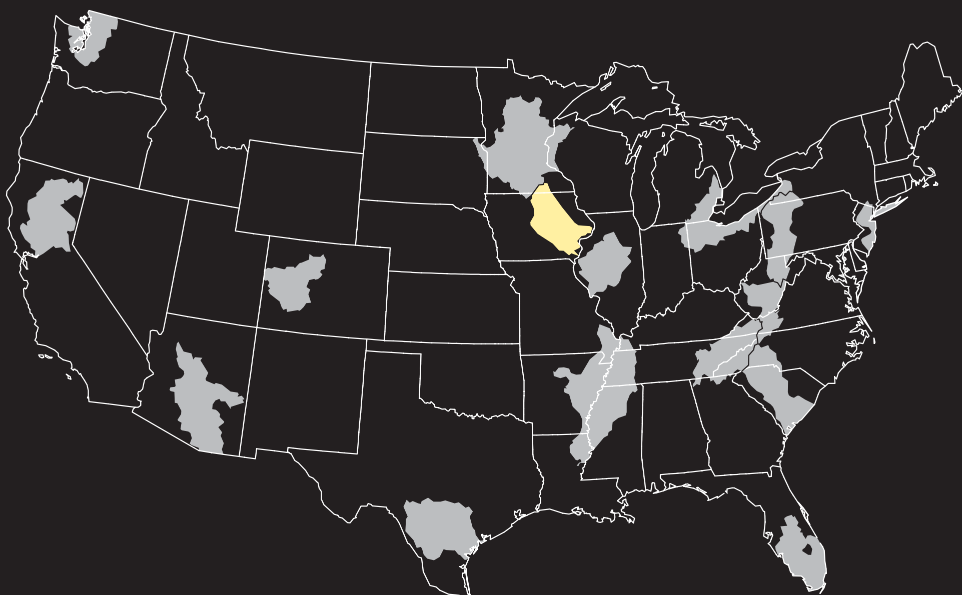
NAWQA

National Water-Quality Assessment (NAWQA) Program
Eastern Iowa Basins



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